

# Influence of Leaf Area Index on the Heat Index of a Tropic Urban Park

Jonathan Willian Zangeski Novais<sup>1</sup>, Danielle da Silva Batista<sup>2</sup>, Renata Luisa Ferreira<sup>3</sup>,  
Roberta Daniela de Souza<sup>4</sup>, Thiago Fernandes<sup>5</sup> and Carlo Ralph De Musis<sup>6</sup>

<sup>1</sup> Universidade de Cuiabá - UNIC

Received: 11 June 2021 Accepted: 1 July 2021 Published: 15 July 2021

7

## Abstract

In the wake of climate change, cities need to adapt to global warming. In this context, the use of afforestation to improve the microclimate may assist in raising the quality of life for population. This objective requires research that analyzes how the variations in parameters related to canopy dynamics, such as the leaf area index (LAI) and photosynthetically active radiation (PAR) can influence thermal comfort indices. To contribute to this research, this study measured the air temperature, relative air humidity, PAR, and LAI on a monthly basis from July, 2017, to June, 2018, in an urban park in a tropical region of Brazil. Kriging maps were created for the heat index (HI), and multiple polynomial regression models were adjusted to estimate the HI using PAR and LAI data. After defining the models, positive and negative variations of LAI were tested to observe if any changes in HI occurred. The simulated results showed greater sensitivity to negative variations in LAI, in which a 50

20

Index terms— afforestation; air temperature; mobile transect; photosynthetically active radiation; relative humidity; thermal comfort.

## 1 Introduction

In the wake of climate change, cities need to adapt to global warming. In this context, the use of afforestation to improve the microclimate may assist in raising the quality of life for population. This objective requires research that analyzes how the variations in parameters related to canopy dynamics, such as the leaf area index (LAI) and photosynthetically active radiation (PAR) can influence thermal comfort indices. To contribute to this research, this study measured the air temperature, relative air humidity, PAR, and LAI on a monthly basis from July, 2017, to June, 2018, in an urban park in a tropical region of Brazil. Kriging maps were created for the heat index (HI), and multiple polynomial regression models were adjusted to estimate the HI using PAR and LAI data. After defining the models, positive and negative variations of LAI were tested to observe if any changes in HI occurred. The simulated results showed greater sensitivity to negative variations in LAI, in which a 50% reduction in LAI decreased the HI by 28%, particularly during the dry period. As the area is a region that experiences considerable variability in terms of humidity and high temperatures throughout the year, conditions conducive to thermal discomfort had often occurred in the study area. This indicates that for tropical regions, even in urban parks, it is important that users pay close attention to their hydration needs and the duration and intensity of their physical activities.

Keywords: afforestation; air temperature; mobile transect; photosynthetically active radiation; relative humidity; thermal comfort. Climate change and its impacts associated with anthropogenic actions including vegetation suppression, land use, and occupation, and the dense and compact set of constructions from constant urban expansion have become the focus of widespread discussion amongst the scientific community (Grimmond et al., 2009; Middel et al., 2014; Petralli et al., 2014). This is due to the changes in the thermodynamic field caused by the decrease in shortwave reflection and increased emission of long waves; this causes an increase in air

## 5 C) HEAT INDEX

---

44 temperature even during the periods of shorter heat stroke duration, intensifying the formation of heat islands  
45 ??Ayoade, 2003;Peng et al., 2012).

46 Artificialized areas, mainly in the central regions of cities, produce greater changes in the local climate.  
47 Consequently, vegetated urban spaces contribute to better thermal comfort and the reduction of heat islands.  
48 This is because of the interception of a part of the solar radiation incident by the tree canopy; the extent of  
49 interception varies based on the species, resulting in differing attenuation of solar radiation. ??Abreu et al.,  
50 2012). Herb et al. (2008) affirmed that the canopy of trees affects the heat transfer of the surface and the  
51 temperature of the soil below it, providing better thermal conditions for pedestrian movement (Souza et al.,  
52 2020).

53 Thus, the variations in leaf area indices (LAI) may influence thermal comfort, especially in tropical regions  
54 with seasonal precipitation. According to ??landert (1982), thermal comfort associated with the presence of  
55 afforestation is mainly related to the canopy density of each tree. Through its leaves, trees are able to absorb  
56 15% to 35% of the received light energy, pass between 30% and 50% of the energy, and reflects the remainder of  
57 the energy (~30% to 40%), during the daytime.

58 The constant concern on promoting the quality of life in cities and the health of the population has fostered  
59 the use of research and different methodologies, to demonstrate the effective action of vegetation on the urban  
60 microclimate (Bueno- Bartholomei, 2003 Ren et al. (2013) confirmed that the population recognizes urban parks  
61 as an oasis amid the dense urban construction model, acting to alleviate the thermal discomfort of heat islands.

62 One way to measure a user's comfort index is the heat index (HI) method proposed by ??teadman (1979a  
63 ??teadman (, 1979b ??teadman (, 1984)). This method is one of the most popular environmental health indices,  
64 providing the basis for heat warnings in many communities of the United States of America ??NOAA, 2009).  
65 The heat index has also been applied in several regions and climates in

## 66 2 Materials and Methods

### 67 3 a) Study area

68 This research was conducted at the Conservation Unit Ilto Ferreira Coutinho Park, located in the central region  
69 of the municipality of Tangará da Serra, state of Mato Grosso, Brazil (Fig. 1). The study area is located at  
70 14°37'08"S and 57°29'09"W, with an altitude of 452 m and spans approximately 12 ha (Melz and Tiago, 2009).  
71 The original growth of semideciduous forest is characterized as Cerrado-Amazonian ecotone. The most abundant  
72 families are Anacardiaceae, Malvaceae, Bignoniaceae, Annonaceae, Apocynaceae, Meliaceae, Miristicaceae, and  
73 Rubiaceae, where 81% of the species are native to the region (Rodrigues, et al., 2015). There are two types of  
74 soils in the study area: red dystrophic latosol (red latosol) and hydromorphic quartzic neosol. Based on the  
75 Köppen climate classification, the climate is Aw which is characterized as hot and humid with rain in the summer  
76 and drought in the winter with wet and dry seasons (Alvares et al., 2013). The surroundings are composed of  
77 commercial areas and single-story residences, with very little shade generated by buildings.

### 78 4 b) Measurement of Environmental Variables and Study

79 Period Air temperature and relative humidity were collected for one year, on a monthly basis, Data collection  
80 commenced in July 2017 and ceased in June 2018, from 8 am to 5 pm, with an hourly collection, at a central  
81 park point; the averages were subsequently calculated. Collection days were preferentially chosen when there was  
82 no rain or cloud, based on the method described in Oke (1982). Measurements were obtained using a portable  
83 microclimate station (Kestrel 4500 Weather Tracker, NK Company, Boothwyn, PA, USA).

84 The incident photosynthetically active radiation (PAR) data and LAI were collected at 12 pm at 15 points  
85 distributed throughout the park; the averages of these values were calculated following the measurement. This  
86 data was measured using a linear ceptometer (AccuPar -LP 80, Decagon Devices, Washington, USA).

87 The mobile transect method was used for geostatistical analysis, with air temperature and relative humidity  
88 data collected every minute during a trip that covered all regions of the park. The collections were made at 8am,  
89 12am, and 5pm , in January and June 2018, to cover the seasonality of the region. The HI was calculated based  
90 on these results, and the semivariograms and kriging map were obtained. Because the sensor is open path, not  
91 aspirated, it was also important that measurements occurred when the air was not completely stagnant during  
92 the study to minimize lags in sensor response (Sun, 2011).

### 93 5 c) Heat index

94 The HI was calculated for thermal comfort analysis, often used for hot regions with low-intensity winds and  
95 where an individual is in the shade. This results in the body thermal sensation based on the air temperature and  
96 relative humidity ??Steadman, 1979b).

97 The HI was proposed by ??teadman (1979a), according to Equation ( ??):
$$HI = -42,379 + 2,049015230 * T_{air} + 10,14333127 * R_{h} - 0,22475541 * T_{air} * R_{h} - 6,83783 * 10^{-3} * (T_{air})^2 - 5,481717 * 10^{-2} * (R_{h})^2 + 1,22874 * 10^{-3} * (T_{air})^2 * R_{h} + 8,5282 * 10^{-4} * T_{air} * (R_{h})^2 - 1,99 * 10^{-6} * (T_{air})^2 * (R_{h})^2 (1)$$

100 where HI is the heat index ( $^{\circ}$ F), T air is the actual air temperature (dry bulb temperature) ( $^{\circ}$ F), and R h is  
101 relative humidity (%). The data in  $^{\circ}$ F was subsequently converted to  $^{\circ}$ C. The HI results were analyzed according  
102 to alert levels detailed in Table 1.

## 103 **6 d) Statistical Analysis**

104 The T-test test was used to verify possible statistically significant differences to air temperature, relative humidity,  
105 and HI, at a significance level of 5%. This was carried out to verify possible differences between the periods, and  
106 the Pearson's correlation was used to identify dependencies between meteorological variables.

107 For spatial analysis, semi-variograms were adjusted to the results of the HI. The semi-variance measures  
108 the degree of dependence between two samples. It increases as the distance between points increases, until it  
109 stabilizes at the point known as the threshold (Co + C1), with half the hope of variance between the pairs of  
110 points separated by a distance "h" represented by the classic model, according to Equation (2) as follows:??(?)  
111 = 1 2??(?) ? [??(?? ?? ) ? ??(?? ?? + ?)]<sup>2</sup> ??(?) ??=1(2)

112 Where ? (h) is the estimator of semi-variance for each distance, h; N(h) is the number of pairs of points  
113 separated by the distance, h; Z(x) is the regionalized variable at point, x; and Z(x+h) is the value of point x+h  
114 ??Burrough and Macdonnell, 1998). The semi-variogram is represented by the plot of h versus h. The theoretical  
115 semi-variogram generated by this function must be adjusted with a theoretical model that provides the parameters  
116 nugget effect (Co), sill (Co + C1), and range (Ao). The degree of spatial dependence of variables was classified  
117 according to Cambardella et al. (1994); there was strong spatial dependence when semi-variograms had a nugget  
118 effect that was 25% from the threshold, moderate when between 25 and 75%, and weak when greater than 75%.  
119 The theoretical semi-variogram models consisted of spherical, exponential, and Gaussian models described by  
120 Andriotti (2003) and Yakamoto and Landim (2013). These models were used to estimate the semi-variance at  
121 any distance between samples using the developed GS + (GS +, 2000) software by Gamma Design Software  
122 and spreadsheets. The selection of most optimal semivariogram adjustment method was important as this is  
123 the reference point from which the spatial correlation structure to be used in the inferential kriging procedure is  
124 interpreted (Dias et al., 2015).

125 The evaluation and selection of most optimal adjustments of experimental semi-variograms were based on the  
126 smallest sum of the squares of weighted deviations (SQDP) and the highest coefficient of determination ( $R^2$ );  
127 Andriotti, 2003; Yakamoto and Landim, 2013). The interpolation and spatialization of the variables were then  
128 carried out using the punctual ordinary kriging; their spatial distribution was subsequently analyzed.

129 For models estimating the HI as a function of PAR and LAI, the multiple polynomial regression method was  
130 applied, using the Solver tool of Microsoft Excel®. This tool uses the generalized reduced gradient (GRG) as the  
131 solution method, adjusting five parameters (A, B, C, D, and E) as per Equation (3):???? ????? = (?? \* ??????  
132 ?? ) + (?? \* ??????? ?? ) + ?? (3)

133 After determining the adjusted equation, a t-test was conducted to compare the calculated and modeled data.  
134 The LAI was varied positively and negatively by 10%, 20%, 30%, 40%, and 50%, to enable projections on how  
135 LAI variation may interfere with HI.

## 136 **7 III.**

## 137 **8 Results**

### 138 **9 a) Hourly and Seasonal Analyses**

139 Hourly averages were determined for air temperature, relative humidity, and HI data for mobile transects  
140 conducted in dry and rainy periods, as shown in Fig. 2. For the wet season, 12 h and 17 h were classified  
141 as "Extreme Caution", according Table 1, and 8 h as "Caution". The greatest discomfort observed occurred at  
142 sunset at 17 h, reaching  $34.52 \pm 1.09$   $^{\circ}$ C.

143 The wet season is the period has the highest incidence of solar radiation, as it is summer in the Southern  
144 Hemisphere; this equates to higher temperatures and relative humidity. During the dry period, the average  
145 Possible edge effects may contribute to the greatest standard deviations observed in during the mornings; this  
146 was a variation of 2.62  $^{\circ}$ C for the wet season and 1.99  $^{\circ}$ C for the dry season. The regions outside the park were  
147 observed to heat up relatively rapidly due to the specific heat of the building materials. This was an occurrence  
148 that had been attenuated during other times as the park heats up.

149 For seasonality analysis, the difference in median values between the two groups for air temperature, relative  
150 humidity, and HI was greater than expected, a statistically significant difference was observed ( $P < 0.001$ ). Thus,  
151 the seasonality results follow local weather patterns.

152 Spatial analyses were conducted to observe the distribution of the HI in the park and possible edge effects.  
153 For this purpose, semi-variograms were calculated according to Table ??.

154 Table ??: Adjustment of semivariograms for heat index: model, nugget effect (Co), sill (Co + C), range (Ao),  
155 determination coefficient ( $R^2$ ), and sum of squares of residuals (SSR) and spatial relationship.

156 The largest nugget effect found (Co) was 0.57, and relatively small values of the nugget effect indicated minor  
157 errors in measurements (Dafonte et al., 2010). With the exception the 12 am measurement during the wet season  
158 in which the adjustment was exponential, all other adjustments were spherical. Of the six schedules analyzed,

## 12 DISCUSSION

---

159 there was a strong spatial dependence in four; according to the classification of Cambardella et al. (1994), there  
160 is only strong spatial dependence when the nugget effect is up to 25% of the sill. Moderate dependency occurred  
161 twice, between 5 pm during the wet season and 12 am in the dry season.

162 The greatest range (A 0 ) occurred at midday in the dry period, with 501.5 m, generating the observed  
163 similarity in the special HI, as shown in Fig. 3. The lack of humidity and diminished leaf area accounted for  
164 the standardization observed in the dry season, as shown in Table ?? and Fig. 3. The range is of fundamental  
165 importance to interpret the semi-variograms, indicating the distance to where sampling points correlate with  
166 each other (Carvalho et al., 2002). This ensures that all neighboring points are so similar that they may be used  
167 to estimate values for any point between them ??Machado et al., 2007).

168 The lowest coefficient of determination was 0.78, at 12am during the wet season, suggesting good model  
169 adjustments. Regarding the sum of the squares of residues (SSR), only the 8 am measurement during the wet  
170 season had values exceeding. As the SSR is a measure of discrepancy between the actual and modeled data, a  
171 small SSR indicates a tight fit between the model and the measured data (Draper and Smith, 1998).

172 The spatial patterns follow the hourly patterns shown in Fig. 2, in which in the spatial analyses of the wet  
173 season showed that thermal discomfort was greater in this season than the dry season. Dense vegetation cools  
174 the air as it prevents radiation from reaching the forest floor (Napoli et al., 2016) and provides a larger surface  
175 area for evaporative cooling. However, the incidence of radiation in the summer season was able to elevate air  
176 temperatures, resulting in higher heat levels during the wet season. According to the Pearson's correlation test  
177 (r), air temperature and relative humidity were negatively correlated ( $r = -0.666$  and  $p > 0.01$ ). This means that  
178 an increase or decrease in air temperature results in an increase or decrease in relative air humidity. Varejão-  
179 Silva (2006) explained that such behavior is caused by the inverse proportionality of the relative air humidity  
180 and the vapor saturation point. Therefore, the relative air humidity will also be inversely proportional to the air  
181 temperature.

182 The annual average LAI was approximately  $6 \text{ m}^2 \text{m}^{-2}$ , demonstrating regional seasonality. These values are  
183 close to those reported by Sanches et al. (2008) who used the Moderate Resolution Imaging Spectroradiometer  
184 (MODIS) satellite and reported values between 5.25 to  $5.54 \text{ m}^2 \text{m}^{-2}$  for another area of the Cerrado-Amazonian  
185 ecotone forest. As the urban park vegetation is a seasonal semi-deciduous forest, leaf loss occurs from August  
186 onwards, decreasing the LAI. Another factor that contributes to lower LAI is the solar declination angle; during  
187 the dry season this angle is higher (Spolador et al., 2006; ??ovai et al., 2018). The greater the zenith angle,  
188 the greater the path traveled by radiation within the canopy, increasing the chance of absorption by leaves and  
189 branches (Senna et al., 2005), this increase is associated due to the measurement technique, which uses the linear  
190 ceptometer. PAR data followed the radiation pattern of the Southern Hemisphere, according to Novais et al.  
191 (2016), and LAI and PAR were strongly correlated ( $r = 0.804$  and  $p > 0.01$ ), to the maximum incidence of PAR  
192 in January, approximately  $2006 \text{ mol m}^2 \text{s}^{-1}$ .

193 The accumulated rainfall throughout the analyzed period was 1968 mm; in July 2017, there was

## 194 10 b) Monthly and Model Analysis

195 no rain whereas February was the雨iest with 431 mm, which is approximately 22% of total annual precipitation.  
196 The seasonal pattern of precipitation in the study area is in line with the regional forecast as rainfall is  
197 concentrated between October and April in the Cerrado region (Dallacort et al., 2011).

198  $???? \cdot ????? = (51.63 * ????? \cdot 1.19) + (107.57 * ????? \cdot 0.11) \pm 216.29 (4)$  The difference between the  
199 mean values of HI real and HI mod was insufficient to reject the possibility that this difference was due to random  
200 sampling variability. There was no statistically significant difference between the groups ( $P = 0.996$ ), justifying  
201 the use of the model to simulate LAI variations.

202 Table 3 presents the annual averages of the HI for each model variations and their respective differences from  
203 the original value. The 50% variation of LAI showed the most concerning results, where three months were  
204 within the "Danger" classification, and the remaining months were in the "Extreme Caution" classification. The  
205 positive variations in LAI contributed to a greater number of months in the "No Warning" classification, ranging  
206 from zero months in this classification to four months for the LAI +50% model.

## 207 11 IV.

## 208 12 Discussion

209 Based on the analysis of hourly average air temperature and relative humidity generated by the spatialized data,  
210 the wet season was more uncomfortable than the dry season. This result differs from the monthly analyses  
211 undertaken at a central point of the park. Such differences in results suggest that the spatial patterns of data  
212 collection as well as the possible influence of clearings and edges, influenced these. The addition of 50% LAI  
213 improved the annual average HI by approximately 8.32%, whereas the decrease resulted in a 27.74% decrease in  
214 the average annual HI. Fig. 5 presents the monthly HI results from the model variations according to the LAI.

215 Using PAR and LAI data, the following model was obtained for HI estimates: results. These results corroborate  
216 the scientific findings from Silva Júnior et al. (2012) for the city of Belém (Pará, Brazil), whereby for the majority  
217 of the afternoon the city is thermally uncomfortable. Neighborhoods with a higher percentage of soil sealing

218 and lower vegetation cover exhibited greater thermal discomfort, indicating that urban elements (paved streets,  
219 houses, buildings, and vehicle routes), influence the city's climate.

220 In terms of the influence of the edge effect, Vasconcelos and Zamparoni (2011) and Morakinyo et al. (2017)  
221 found that the effectiveness of trees to improve daytime thermal comfort reduces with increasing urban density  
222 whereas the opposite was true for the nighttime. Therefore, as the park is not influenced by external shading  
223 due to low construction density and people do not visit the park at night, there is no problem using species that  
224 have higher LAI, as it is expected that only daytime comfort occurs. This highlights the importance of urban  
225 planning to present solutions to promote quality of life within a healthy environment.

226 The most uncomfortable time was at 5 pm during the wet season, suggesting that despite the high LAI of  
227 this period, which mitigates the incidence of solar radiation, air exchange is reduced, making heat dissipation  
228 difficult. The cooling effect of vegetation is likely to be lower at night when there is very little transpiration.  
229 This means less evaporative cooling (Richards et al., 2020) because of the trapped heat and humidity within the  
230 urban canopy layer, compared with the rapid nocturnal cooling of open areas (Fahmy et al. 2010). Boone (2008)  
231 explains that humidity often creates a temperature that feels hotter than reality. This is because the body cools  
232 with the evaporation of sweat due to the consumption of latent heat on the surface of the skin. However, when  
233 air humidity rises, there is a decrease in the rate of sweat evaporation, causing greater heat retention and leading  
234 to discomfort and stress ??Delworth et al., 1999).

235 In terms of the analysis of monthly averages, the temperature decreases in September (the dry season), may  
236 be related to cold fronts, where there are sharp drops in solar incidence due to the presence of cloudiness (Biudes  
237 et al., 2015).

238 For model analysis, the annual average LAI was approximately  $6 \text{ m}^2\text{m}^{-2}$ ; this is a relatively high value  
239 compared to cerrado forests, where Hoffman et al. Thus, whilst dense canopy does contribution to thermal  
240 comfort, its contribution is not as great as the decrease in LAI, which leads to greater variations in HI, making  
241 the HI reach  $40.25^\circ\text{C}$  (extreme Caution Alert Level); this constitutes a ~28% increase in relation to measured  
242 values.

243 Despite the general consensus that urban parks are the places of leisure and exercise as well as oases within the  
244 urban area, in tropical areas, greater attention should be given to vulnerable users of the park, for instance, those  
245 susceptible to cramps, sunstroke and likely exhaustion, and possible brain damage due to prolonged exposure to  
246 more intense physical activities. This is because the heat indices during the dry season was largely unsatisfactory.

247 V.

## 248 13 Conclusion

249 The LAI influences the HI, and this influence is more pronounced in models that decrease the amount of leaves.  
250 A 50% reduction in LAI caused a 28% increase in the HI, being classified as "Extreme Caution" alert level during  
251 the dry season which was found to be more susceptible to the changes in the LAI. Hourly analysis showed that  
252 the evening, especially in the wet season, was of greater concern, as there was a lack of thermal comfort even  
253 in shaded areas. The possible nighttime discomfort generated by the heat retained in the park is insufficient  
254 to cause major concern, as park visit is typically limited to the daytime. Although urban parks are recognized  
255 as a place for leisure and physical activities, greater care is suggested during the use of urban parks in tropical  
256 regions. It is recommended that park users equip themselves with light clothing, hydration, and are careful with  
257 strenuous activities, avoiding the periods of greatest thermal discomfort.

1 2 3 4

<sup>1</sup>Abbreviations: GRG: generalized reduced gradient; HI: heat index; LAI: leaf area index; MODIS: Moderate Resolution Imaging Spectroradiometer; PAR: photosynthetically active radiation; SQDP: sum of squares of weighted deviations; SSR: sum of the squares of residues.

<sup>2</sup>© 2021 Global JournalsInfluence of Leaf Area Index on the Heat Index of a Tropic Urban Park

<sup>3</sup>© 2021 Global Journals Year 2021 B Influence of Leaf Area Index on the Heat Index of a Tropic Urban Park

<sup>4</sup>B © 2021 Global JournalsInfluence of Leaf Area Index on the Heat Index of a Tropic Urban Park

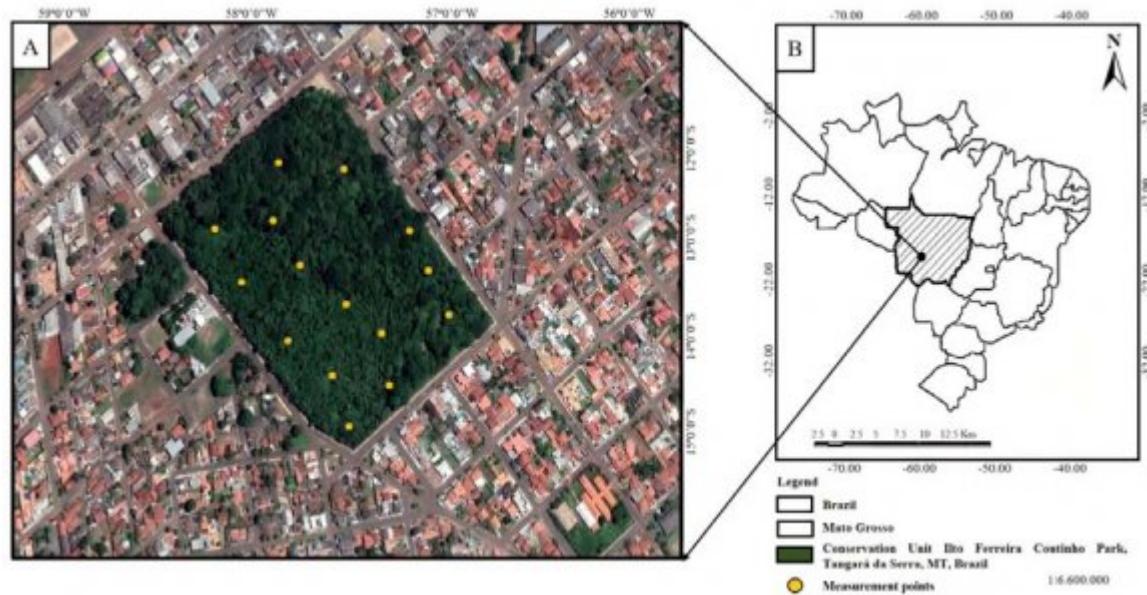


Figure 1:

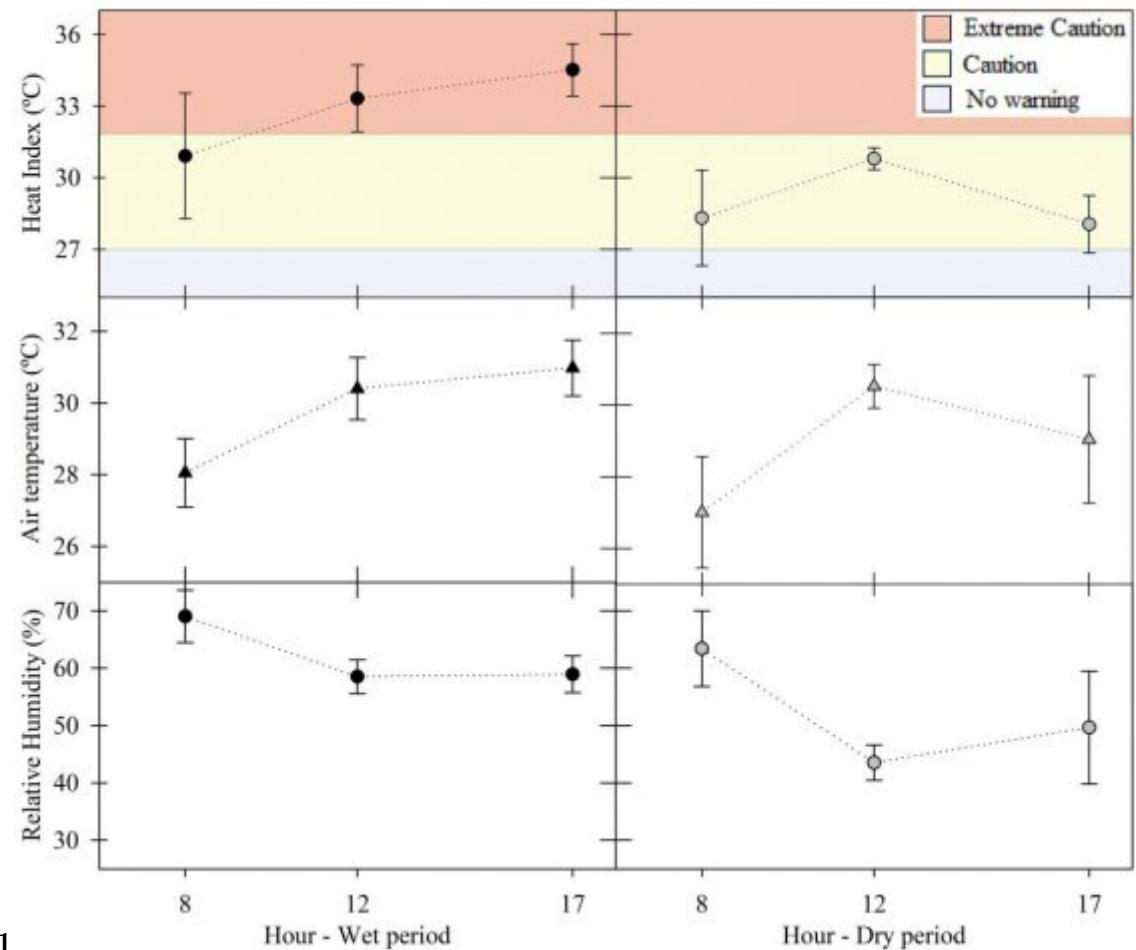


Figure 2: Figure 1 :

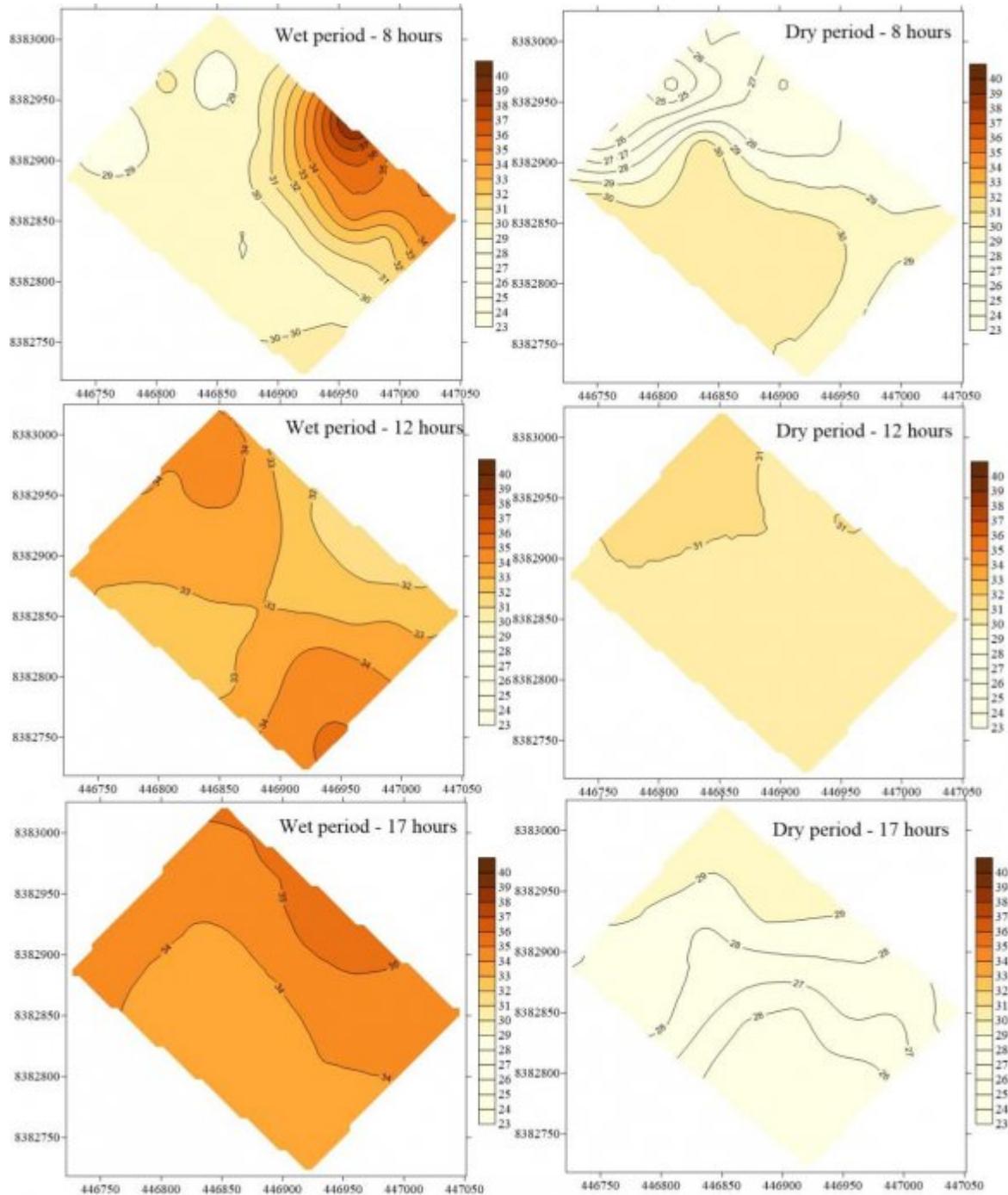
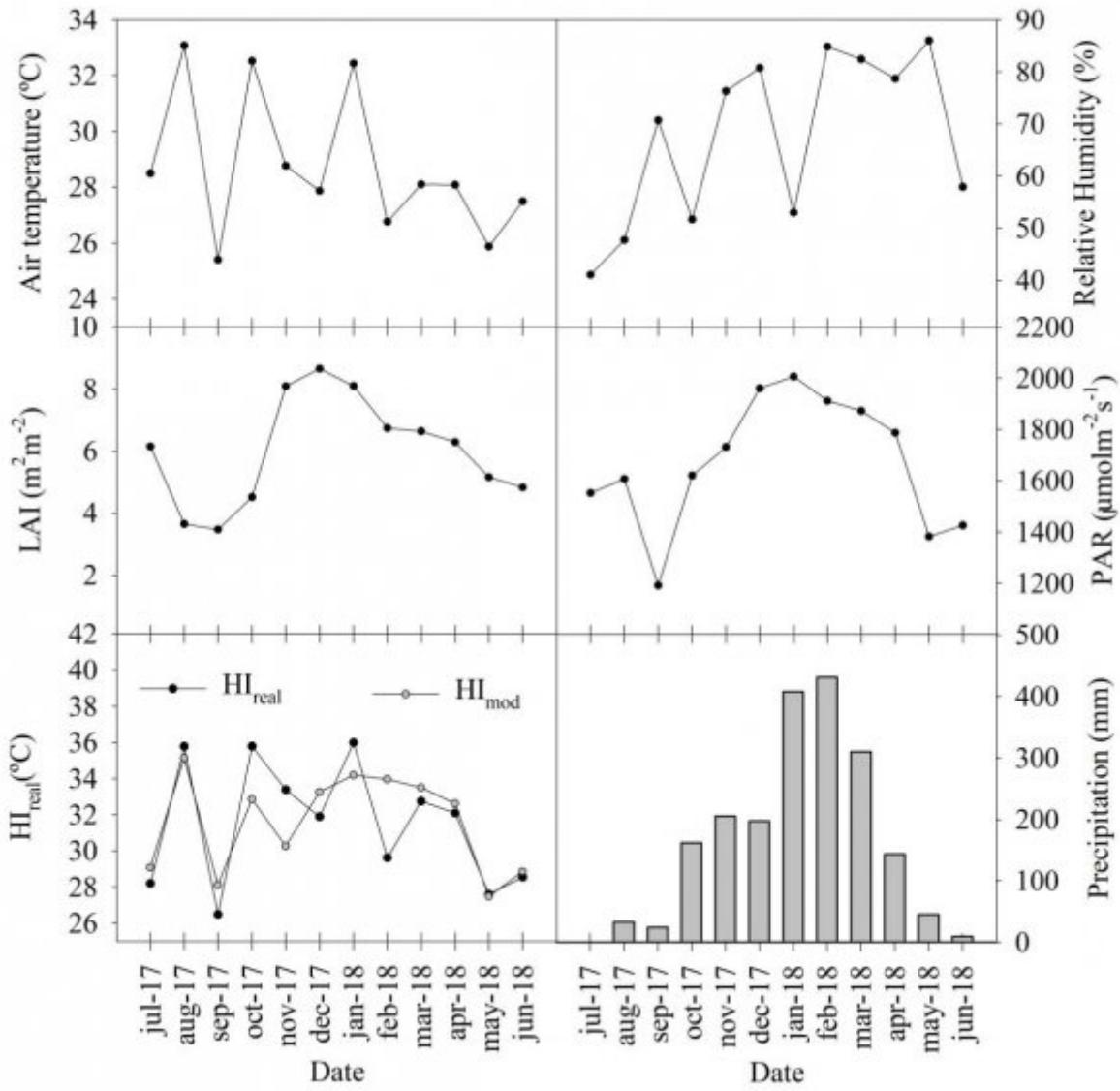


Figure 3:



2

Figure 4: Figure 2 :

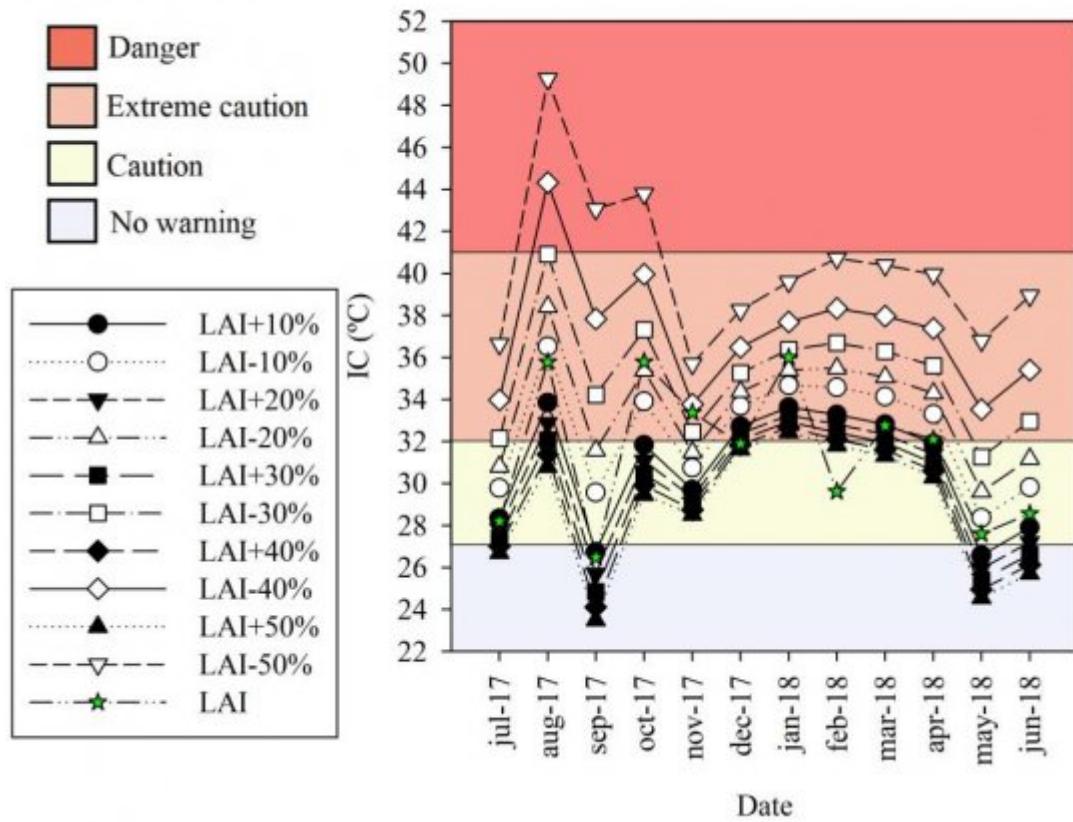


Figure 5: B

1

Alert level	Heat index (HI) °F	Heat index (HI) °C	Symptoms
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 heart attack and risk of imminent cerebral vascular accident.

[Note: Source: Adapted from the National Weather Service Weather Forecast Office, NOAA.]

Figure 6: Table 1 :

## 13 CONCLUSION

---

**3**

		0%	10%	20%	30%	40%	50%					
HI	LAI +	31.50	430.77	32.42	30.17	33.58	29.67	35.11	29.25	37.21	28.89	40.25
	LAI -											
Variation	AI +	-	-2.34%		-4.24%		-5.83%		-7.17%		-8.32%	
	LAI -		2.88%		6.58%		11.44%		18.11%		27.74%	

[Note: \* LAI + corresponds to positive variations in leaf area index and LAI-to negative variations.]

Figure 7: Table 3 :

258 .1 Funding

259 This work was supported by the Mato Grosso Research Support Foundation-FAPEMAT [grant number  
260 0194288/2017].

261 [Climatologia] , Climatologia . 10.5380/abclima.v24i0.58644. <http://dx.doi.org/10.5380/abclima.v24i0.58644> p. 24.

262 [Meteorol] , Meteorol . 10.1007/s10546-013-9883-1. 151 p. .

263 [Marimon et al. ()] , B S Marimon , E D S Lima , T G Duarte , L C Chieregatto , J A Ratter , Observations On  
264 The , Vegetation , Mato , Brazil Iv Grosso , An , Of , -Amazonian Forest Ecotone; The Cerrado-Amazonian  
265 Forest Ecotone In Brazil; Et Cerrado , Al . 10.1017/S0960428606000576. <https://doi.org/10.1017/S0960428606000576> Journal of Botany 2006. 63 (2-3) p. 323.

266 [Porangaba and Amorim ()] , G F O Porangaba , M C C Amorim . 2017.

267 [Krayenhoff et al. ()] A multi-layer radiation model for urban neighbourhoods with trees, E S Krayenhoff , A  
268 Christen , A Martilli , T R Oke . 2014. (Boundary-Layer)

269 [Sun ()] 'A street thermal environment study in summer by the mobile transect technique'. C Y Sun .  
270 10.1007/s00704-011-0444-6. Theoretical and applied climatology 2011. 106 (3-4) p. .

271 [Morakinyo et al. ()] 'A study on the impact of shadow-cast and tree species on in-canyon and neighborhood's  
272 thermal comfort'. T E Morakinyo , L Kong , K K L Lau , C Yuan , E Ng . Doi: 10.1016 / j.buildenv.2017.01.005.  
273 Building and Environment 2017. 115 p. .

274 [Novais et al. ()] 'Albedo do Solo abaix do Dossel em Área de Vochysia divergens Pohl no Norte do Pantanal'.  
275 J W Z Novais , L Sanches , L B D Silva , N G Machado , A M Aquino , O B Pinto Junior . 10.1590/0102-  
276 778631220150001. Revista Brasileira de Meteorologia 2016. 31 (2) p. .

277 [Grimmond and Oke ()] 'An evaporation-interception model for urban areas'. C S B Grimmond , T R Oke .  
278 10.1029/91WR00557. Water Resour. Res 1991. 27 p. .

279 [Andriotti ()] J L S Andriotti . Fundamentos de estatística e geoestatística, 2003. (No. 551: 519.2 AND)

280 [Junior et al. ()] 'Análise da distribuição espacial do conforto térmico da cidade de Belém, PA no período menos  
281 chuvoso'. J D A S Junior , A C L Costa , J C B Pezzuti , R F Costa , D Galbraith . 10.26848/rbgf.v5.2.p218-  
282 232. Revista Brasileira de Geografia Física 2012. 5 (2) p. .

283 [Análise de ilhas de calor diagnosticas por meio de transectos móveis em Assis] Análise de ilhas de calor diag-  
284 nosticas por meio de transectos móveis em Assis, 10.4000/confins.12729. Doi: 10. 4000/confins.12729. Cândido  
285 Mota, Maracá e Tarumã (SP). Confins. 33 p. . (Revue francobrésilienne de Géographie)

286 [Draper and Smith ()] Análise de regressão aplicada, N R Draper , H Smith . 1998.

287 [Andrade et al. ()] 'Atmospheric Pollution and Meteorological Parameters in the City of Cuiabá-MT'. L P  
288 Andrade , M C J A Nogueira , F M M Santos , J S Nogueira , C R Musis , J Novais , WZ . 10.15341/mese(2333-  
289 2581)/06.05.2019/003. Modern Environmental Science and Engineering 2019. 5 (6) p. .

290 [Abreu et al. ()] Avaliação da Termo-Regulação em Diferentes Espécies Arbóreas, L V Abreu , L C Labaki ,  
291 Encontro , De , Do , Construído . 2008. p. 12.

292 [Abreu-Harbich et al. ()] 'Bioclima térmico como fator de planejamento urbano e arquitetônico em climas  
293 tropicais -o caso de Campinas'. L V Abreu-Harbich , L C Labaki , A Matzarakis . Doi: 10.1007/ s00704-  
294 013-0886-0. Brasil. Urban Ecosystems 2014. 17 (2) p. .

295 [Richards et al. ()] Differential air temperature cooling performance of urban vegetation types in the tropics.  
296 Urban Forestry & Urban Greening, D R Richards , T K Fung , R N Belcher , P J Edwards .  
297 10.1016/j.ufug.2020.126651. 2020. p. 126651.

298 [Dallacort et al. ()] 'Distribuição das chuvas no município de Tangará da Serra, médio norte do Estado de  
299 Mato Grosso'. R Dallacort , J A Martins , M H Inoue , P S L De Freitas , A J Coletti . Doi: 10.  
300 4025/actasciagron.v33i2.5838. Brasil. Acta Scientiarum. Agronomy 2011. 33 (2) p. .

301 [Ren et al. ()] 'Estimation of the relationship between urban park characteristics and park cool island intensity  
302 by remote sensing data and field measurement'. Z Ren , X He , H Zheng , D Zhang , X Yu , G Shen , R Guo  
303 . Doi: 10.3390/ f4040868. Forests 2013. 4 (4) p. .

304 [França ()] Estimativa de índices de conforto térmico por meio do uso de transecto móvel em Sorriso/MT. Revista  
305 Nativia, M S França . 10.31413/nativa.v6i6.5820. <http://dx.doi.org/10.31413/nativa.v6i6.5820>  
306 2018. Sinop-MT. 6 p. .

307 [França et al. ()] 'Estimativa do conforto térmico na cidade de Cuiabá/ MT'. M S França , S M B De França ,  
308 M C D J A Nogueira , J De Souza Nogueira . 10.18316/1981-8858.16.22. <http://dx.doi.org/10.18316/1981-8858.16.22> Revista de Ciências Ambientais 2016. 10 (1) p. .

309 [Cambardella et al. ()] 'Field-scale variability of soil properties in central Iowa soils'. C A Cambardella , T  
310 B Moorman , J M Novak , T B Parkin , D L Karlen , R F Turco , A E Konopka . 10.2136/sssaj1994.03615995005800050033x. Soil science society of America journal 1994. 58 (5) p. .

311

315 [Senna et al. ()] 'Fração de radiação fotossinteticamente ativa absorvida pela floresta tropical amazônica: Uma  
316 comparação de medições de campo, modelagem e sensoriamento remoto'. M C Senna , M Costa , & Y E  
317 Shimabukuro . *Journal of Geophysical Research* 2005. (G1) p. 110. (Biogeosciences)

318 [Carvalho et al. ()] 'Geoestatística na determinação da variabilidade espacial de características químicas do  
319 solo sob diferentes preparos'. J R P D Carvalho , P M D Silveira , S R Vieira . Doi: 10. 1590/S0100-  
320 204X2002000800013. *Pesquisa Agropecuária Brasileira* 2002. 37 (8) p. .

321 [Maciel et al. ()] 'Ground cover and its influence on temperature of urban microclimate of Cuiabá-MT'. Rezende  
322 Maciel , C Nogueira , M C D J A De Souza Nogueira , J . *Caminhos de Geografia* 2011. (39) p. 12.

323 [Middel et al. ()] 'Impact of urban form and design on mid-afternoon microclimate in Phoenix Local Climate  
324 Zones'. A Middel , K Häb , A J Brazel , C A Martin , S Guhathakurta . 10.1016/j.landurbplan.2013.11.004.  
325 *Landscape and Urban Planning* 2014. 122 p. .

326 [Alves et al. ()] 'Impacto da morfologia de parque urbano no microclima e no conforto térmico de Cuiabá-Brasil'.  
327 A C M Alves , M C D J A Nogueira , F M De Moura Santos , C R De Musis , J De Souza Nogueira . *Revista  
328 Brasileira de* 2019.

329 [Bartholomei ()] *Influência da vegetação no conforto térmico urbano e no ambiente construído*, C L B Bartholomei  
330 . 2003.

331 [Ayoade ()] *Introdução à Climatologia para os Trópicos*, J O Ayoade . 2007. Bertrand Brasil, Rio de Janeiro.

332 [Rodrigues et al. ()] 'Inventário florístico no entorno das trilhas do parque natural municipal "Ilto Ferreira  
333 Coutinho". P P Rodrigues , I T S Gomes , M L S Simon , J R S Nunes , R B Añez . *Anais: Resumos  
334 Expandidos. Vi Simpósio Da Amazônia Meridional Em Ciências Ambientais Scientific Electronic Archives*,  
335 2015. 8.

336 [Alvares et al. ()] *Köppen's climate classification map for Brazil*. Metereol, C A Alvares , S Jl , P C Sentelhas ,  
337 G Sparovek . 10.1127/0941-2948/2013/0507. 2013. p. 6.

338 [Fahmy et al. ()] 'LAI based trees selection for mid latitude urban developments: A microclimatic study in  
339 Cairo'. M Fahmy , S Sharples , M Yahiya . 10.1016/j.buildenv.2009.06.014. <https://doi.org/10.1016/j.buildenv.2009.06.014> Egypt. *Building and Environment* 2010. 45 (2) p. .

341 [Dafonte et al. ()] 'Mapping of soil micronutrients in an European Atlantic agricultural landscape using ordinary  
342 kriging and indicator approach'. J D Dafonte , M U Gutián , J Paz-Ferreiro , G M Siqueira , E  
343 V Vázquez . 10.1590/S0006-87052010000500018. Doi:[doi.org/10.1590/S0006-87052010000500018](https://doi.org/10.1590/S0006-87052010000500018)  
344 *Bragantia* 2010. 69 p. .

345 [Varejão-Silva ()] *Meteorologia e climatologia: versão digital 2*, M A Varejão-Silva . 2006. Recife: Esalq.

346 [Napoli et al. ()] 'Modeling tree shade effect on urban ground surface temperature'. M Napoli , L Massetti , G  
347 Brandani , M Petralli , S Orlandini . Doi: 10.2134/jeq2015.02.0097. *Journal of environmental quality* 2016.  
348 45 (1) p. .

349 [Monteiro et al. ()] *Modelos Preditivos de Estresse Termo-Fisiológico: estudo empírico comparativo em ambientes  
350 externos*, L M Monteiro , M P Alucci , Encontro , De , No , Construído . 2008. p. 12.

351 [Dias et al. ()] 'Métodos de ajuste de semivariogramas para modelagem espacial de íons de precipitação pluvial  
352 em Cuiabá'. M V R Dias , M De Carvalho Alves , L Sanches . 10.5902/2179460X12101. *Brasil. Ciência e  
353 Natura* 2015. 37 (2) p. .

354 [National Weather Service Glossary (2009)] *National Weather Service Glossary*, <http://wl.weather.gov/glossary> 2009. August 2020. p. 12. NOAA (National Oceanic and Atmospheric Administration

356 [Nóbrega and Verçosa ()] 'O microclima e o (des) conforto térmico em ambientes abertos na cidade do recife'. R  
357 S Nóbrega , T Verçosa . *Revista de Geografia (Recife)* 2011. 28 (1) p. .

358 [Vasconcelos and Zamparoni ()] *Os efeitos da urbanização no microclima no bairro Morada da Serra, Cuiabá-MT.  
359 Raega-O Espaço Geográfico em Análise*, L C Vasconcelos , C A G P Zamparoni . 10.5380/raega.v23i0.24922.  
360 <http://dx.doi.org/10.5380/raega.v23i0.24922> 2011. 23.

361 [Biudes et al. ()] 'Patterns of energy exchange for tropical ecosystems across a climate gradient in Mato Grosso'.  
362 M S Biudes , G L Vourlitis , N G Machado , P H Z De Arruda , G A R Neves , F De Almeida Lobo . Doi:  
363 10.1016 / j.agrformet.2014.12.008. *Brazil. Agricultural and Forest Meteorology* 2015. 202 p. . (J.)

364 [Burrough et al. ()] *Principles of geographical information systems*, P A Burrough , R McDonnell , R A McDonnell  
365 , C D Lloyd . 2015. Oxford university press.

366 [Melz and Tiago ()] 'Propriedades físico-químicas e microbiológicas do solo de um Parque em Tangará da  
367 Serra, MT, uma área de transição entre Amazônia e Cerrado'. E M Melz , P V Tiago . 10.1590/S0044-  
368 59672009000400011. *Acta Amazonica* 2009. 39 (4) p. .

369 [Spolador et al. ()] 'Radiação fotossinteticamente ativa em uma floresta de transição Cerrado-Amazônica'. J  
370 Spolador , L Sanches , M H Costa . *Revista Brasileira de Meteorologia* 2006. 21 (3b) p. .

371 [Hoffmann et al. ()] 'Seasonal leaf dynamics across a tree density gradient in a Brazilian savanna' W A Hoffmann  
372 , E R Da Silva , G C Machado , S J Bucci , F G Scholz , G Goldstein , F C Meinzer . 10.1007/s00442-005-  
373 0129-x. *Oecologia* 2005. 145 (2) p. .

374 [Malhado et al. ()] *Seasonal leaf dynamics in an Amazonian tropical forest. Forest ecology and management*, A  
375 C Malhado , M H Costa , F Z De Lima , K C Portilho , D N Figueiredo . 10.1016/j.foreco.2009.06.002.  
376 <https://doi.org/10.1016/j.foreco.2009.06.002> 2009. 258 p. .

377 [Herb et al. ()] 'Simulação da temperatura da superfície do solo para diferentes coberturas do solo' W R Herb ,  
378 B Janke , O Mohseni , Stefan , Hg . 10.1016/j.jhydrol.2008.04.020. *Journal of Hydrology* 2008. 356 (3-4) p. .

379 [Machado et al. ()] 'Soil nutrients and vegetation structure in a neotropical seasonal wetland' N G Machado  
380 , L Sanches , L B Silva , J W Z Novais , A M Aquino , M S Biudes , . . Nogueira , JS . Doi: 10.  
381 15666/aeer/1302\_289305. *Applied ecology and environmental research* 2015. 13 (1) p. .

382 [Novais et al. ()] 'Space-temporal variation of PAR reflected by the soil and transmitted by the canopy in a  
383 floodplain forest of Mato Grosso State' J W Z Novais , L Sanches , V R D M Dias , N G Machado , L B D  
384 Silva , A M Aquino . Doi: 10.5902/1980509835097. *Brazil. Ciencia Florestal* 2018. 28 (4) p. .

385 [Peng et al. ()] 'Surface urban heat island across 419 global big cities' S Peng , S Piao , P Ciais , P Friedlingstein  
386 , C Ottle , F M Breón , . . Myneni , RB . 10.1021/es2030438. *Environmental science & technology* 2012. 46  
387 (2) p. .

388 [Pereira et al. ()] 'Temporal dynamic of CO<sub>2</sub> efflux in a savanna fragment in Mato Grosso' S P Pereira , J  
389 W Z Novais , O B P Júnior , C R De Musis , L P De Andrade , T D O Joaquim , M A Pierangeli .  
390 10.6008/CBPC2179-6858.2018.002.0004. *Revista Ibero-Americana de Ciências Ambientais* 2018. 9 (2) p. .

391 [Silva and Streck ()] 'Tendências das séries históricas do índice de calor no município de Santa Maria-RS' S D  
392 Silva , N A Streck . 10.1590/0103-8478cr20131345. *Ciência Rural* 2014. 44 (8) p. .

393 [Steadman ()] 'The assessment of sultriness. Part I: A temperature-humidity index based on human physiology  
394 and clothing science' R G Steadman . 10.1175/1520-0450(1979)018<0861:TAOSPI>2.0.CO;2. *Journal of  
395 applied meteorology* 1979. 18 (7) p. .

396 [Steadman ()] 'The assessment of sultriness. Part II: effects of wind, extra radiation and barometric pressure on  
397 apparent temperature' R G Steadman . 10.1175/1520-0450(1979)018<0874:TAOSPI>2.0.CO;2. *Journal of  
398 Applied Meteorology* 1979. 18 (7) p. .

399 [Oke ()] 'The energetic basis of the urban heat island' T R Oke . Doi: 10.1002/qj.49710845502. *Quarterly  
400 Journal of the Royal Meteorological Society* 1982. 108 (455) p. .

401 [Souza et al. ()] 'Urban microclimate in vegetated and non-vegetated areas in rainy and sunny conditions' R W  
402 Z Souza , M A Pierangeli , M Lansanova , T Fernandes , V S P Hoki , P J Souza . 10.5380/raega. Raega-O  
403 *Espaço Geográfico em Análise* 2020. 47 (1) p. .

404 [Petralli et al. ()] 'Urban planning indicators: useful tools to measure the effect of urbanization and vegetation on  
405 summer air temperatures' M Petralli , L Massetti , G Brandani , S Orlandini . 10.1002/joc.3760. *International  
406 Journal of Climatology* 2014. 34 (4) p. .

407 [Grimmond et al. ()] 'Urban surface energy balance models: model characteristics and methodology for a  
408 comparison study' C S B Grimmond , M Best , J Barlow , A J Arnfield , J J Baik , A Baklanov , . .  
409 Clark , P . 10.1007/978-3-642-00298-4\_11. *Meteorological and Air Quality Models for Urban Areas*, (Berlin,  
410 Heidelberg) 2009. Springer. p. .

411 [Yakamoto and Landim ()] J Yakamoto , P Landim . *Geoestatística: Conceitos e Aplicações. 1<sup>a</sup> Edição*, (São  
412 Paulo) 2013. Oficina de Textos.

413 [Rodriguez-Aval Llardent ()] *Zonas verdes y espacios libres en la ciudad. Instituto de estudios de administración  
414 local*, L Rodriguez-Aval Llardent . 1982. Madrid.

415 [Ferreira et al. ()] 'Áreas verdes urbanas: uma contribuição aos estudos das ilhas de frescor' L Ferreira , S T  
416 Carrilho , P C Mendes . *Brazilian Geographical Journal: geosciences and humanities research medium* 2015.  
417 6 (2) p. .

418 [Sanches et al. ()] 'Índice de área foliar em floresta de transição amazonia cerrado em diferentes métodos de  
419 estimativa' L Sanches , N L R De Andrade , J De Souza Nogueira , M S Biudes , G L Vourlitis . Doi: 10.  
420 5902/2179460X9750. *Ciência e Natura* 2008. 30 (1) p. .