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Analysis of the urban heat island in representative points of the city of Bayeux/PB

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Abstract

Urban growth has generated several socio-environmental problems and has altered the quality of life of people living in these environments. Due to the disorderly growth of cities and the various forms of urban land use and occupation, changes in the thermal field of these areas have occurred and caused the formation of urban heat islands and thermal discomfort in urban environments. Thus, the need to understand the formation of heat islands in these areas and the study of their causes and consequences grows. Given this context, the present work intends to study the urban climate of the city of Bayeux / PB, specifically the urban thermal field, and the formation of heat islands. For the accomplishment of the research, initially a bibliographical survey of the subject in question was made. Subsequently experimental points of meteorological data collection (temperature and relative air humidity) were defined in the metropolitan area of the city of João Pessoa, specifically in the municipality of Bayeux / PB. These points were defined based on the different types of land use and cover in the study area. The following experimental points were defined: a point in the center of the city of Bayeux / PB, another point on the banks of the BR230 direction Bayeux, and a reference point in a remnant of Atlantic forest. To obtain the urban heat island the reference point was used as a parameter of the climatic conditions of a natural environment. The data of temperature and relative humidity were collected through thermometers (HOBO U-10), which were placed on steel tripods (1.5 meters high) and monitored at uninterrupted intervals of 1 and 1 hour during the dry period and rainy region. The analysis of the data points to the formation of urban heat islands in the two periods evaluated in the city of Bayeux / PB, being the center of the city, the most critical area with the most intense heat islands. The vegetative cover played a predominant role in the climatic mitigation of the experimental samples as well as the presence of precipitation. The areas with impermeable soil cover presented the largest heat islands and contributed to the thermal discomfort of the study area.
Keywords: Urban Climate, Thermodynamic Field, Urban Heat Island.

1. Introduction

The intense urbanization process in the last decades, have significantly altered the natural landscape and compromised the climatic conditions of urban areas. This rapid disorderly growth led to a precarious planning of urban infrastructure, causing the use and occupation of the land in a disorderly way obeying only the speculative logic of capital. The precarious planning of urban areas with the reduction of green areas, together with local climatic characteristics, are the main factors responsible for extreme events, such as floods and the formation of urban heat islands (ICU), faces of the urban climate. Studies on urban climate began in the eighteenth century in Europe, where cities with strong industrial activities, with different forms of use and recoating of the ground, reduction of the vegetal cover, went through modifications in the chemical and physical patterns of the atmosphere, originating thus, the urban climate.

In Brazil, the urbanization process has a greater emphasis between the 1950s and 1980s, with the growth of the rural exodus and the vegetative growth of the urban population. In the second half of the last century, with the awakening of environmental concerns, large volumes of work on the urban climate began to be produced with emphasis on studies involving the formation of heat islands (Gonçalves, 2003; Rizwan et al., 2008). The study of the urban climate in Brazil has as main reference work the thesis of Monteiro (1976), where he developed a theoretical and methodological model that is a reference for urban climatic studies in Brazil.

Monteiro (1976) developed the Urban Climate System (SCU), in which he says, is defined as an open, adaptive and evolutionary system, composed of the local climate and the city. This system is classified into three subsystems; thermodynamic, which is related to the ambient thermal comfort; the Physical-chemical that deals with the quality of the air over the city and the Meteoric Hydro, which deals with the meteoric impact (rains and floods) on the city.

According to data from the Brazilian Institute of Geography and Statistics (IBGE), in 2010 the urban population in Brazil reached 84.35% in some urban centers, reaching 95.8% of its total population in the country living in urban areas. The concentrations of the Brazilian population in the urban centers show several socioenvironmental problems, which directly influence the quality of life of the urban population (IBGE, 2010). Santos and Silveira (2003) affirm that the main cause of urbanization in Brazil is the population displacement in the different regions. The main reasons that lead to this displacement are: opportunities for economic growth, quality of life and higher education. Thus, all this demand on a geographic space changes the environmental landscape, because there will be a greater consumption of resources, greater generation of energy, pollution and constructions that will favor the increase of temperature, the formation of the islands of heat. Thus, one of the ways in which urbanization interferes with climate patterns is explained by the formation of the urban heat island.

Bertello (2004), defines the heat island as a typical phenomenon of cities, where the lack of atmospheric circulation and vegetation, added to large expanses of concrete, causes an increase in temperature in the urban environment. For the most part, Brazilian cities are unprepared to serve the huge contingent of people, which has negative consequences directly linked to climate phenomena. Considered by many authors as a complex system, the urban climate is unique to the city, because it is in this environment that strong changes occur in atmospheric patterns, impacting circulation, air dispersion, albedo and heat storage, evapotranspiration and surface energy balance (Arnfield, 2003; Kanda, 2006). Thus, heat islands are the main manifestation of the urban climate and one of the main environmental problems of the 21st century in urban environments (Rizwan and Dennis, 2008).

The islands of heat are characterized by three main aspects: the shape, intensity and location of its hottest core. These characteristics depend on the conditions of each city, time of year, weather, geographic location, natural characteristics and the thermal properties of the materials present on the surface (Voot and Oke, 2003). As noted by Ayoade (1986), the urban heat island phenomenon has the following characteristics for its formation: urban areas are warmer than the surrounding countryside, particularly at night; the thermal capacity of heat and the conductivity of the urban surfaces cause absorption of the radiation during the day and its release at night; addition of heat through the combustion and metabolism of the human body and anthropogenic activities.

In view of this context, this study is presented, with the main objective of studying the formation of the heat island in some ready representative of the urban network of the city of Bayeux.

2. Material and methods

The Municipality of Bayeux has a land area of 27,536 km², with an estimated population of 96,716 thousand inhabitants (IBGE, 2010), and a population density of 3,188.76 inhab / km². The municipality has an important representative area of the mangrove ecosystem, which represent about 60% of the municipal territory. Bayeux is located in the coastal portion of the state of Paraíba, between the municipalities of Santa Rita / PB and João Pessoa, between the coordinates: Latitude: -7.12499, Longitude: -34.9321, South Longitude 7 ° 7'30", West Longitude 34 ° 55'56 " (Figure 1). The predominant vegetation in this municipality is the subperenifolia forest, with parts of forest subcaducifolia and transition of Cerrado and Forest. The average annual rainfall is approximately 1,800 mm and the average annual evaporation is 1,400 mm. The climate of the municipality is hot and humid, with rains of autumn and winter, according to the classification of Koppen. According to Carrilho et al., (2010) the dry period in the region begins in August, extending until February, with a total of seven months drier. The temperature of the area is strongly influenced by the sea, with an annual average of 27 ºC (Carrilho et al., 2010).

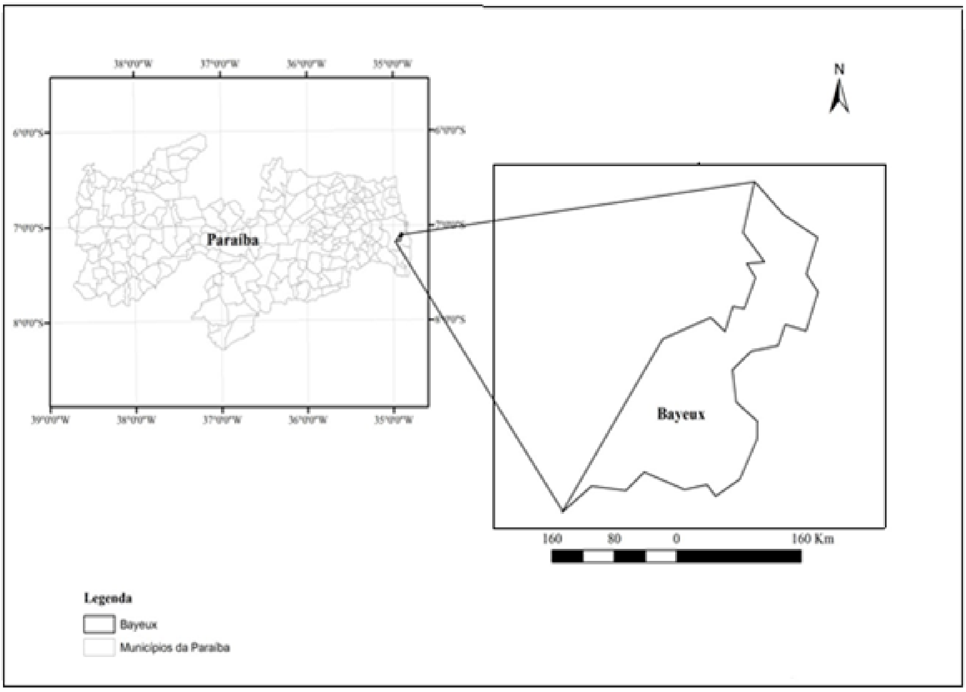

Figure 1 - Map of the study area.

For the accomplishment of the research, initially a bibliographical survey of the subject in question was made. Subsequently, experimental points of meteorological data collection, temperature and relative humidity were defined in the metropolitan area of the city of João Pessoa, specifically in the municipality of Bayeux. These points were defined based on the different types of land use and cover in the study area. A point in the center of the city of Bayeux / PB, another point on the banks of the BR-230 direction Bayeux, was defined as the reference point in a remnant of Atlantic forest, where the islands were defined urban heat of the city. In order to obtain the heat island, the temperature difference between the reference point with similar conditions to a rural and an urbanized environment is verified.

To verify the intensity of the heat island, the classification adapted from García (1996) was used, establishing that 0ºC <IC ≤ 2ºC the island of heat is of Weak Magnitude; 2ºC <IC ≤ 4ºC is considered of Medium Magnitude; 4ºC <IC ≤ 6ºC is considered of Strong Magnitude and, IC> 6ºC is considered of Very Strong Magnitude. At 0ºC the area is considered neutral, that is, it does not present an island of heat or freshness and when the values presented are below zero, it means that an island of freshness is characterized. The data collected at these experimental points are aimed at the atlaclimate monitoring of the variables: temperature and relative humidity of the air, because through these variables one can calculate the formation of heat islands in the study area. Measurements of these variables were performed in two distinct periods for the region: one dry period (December, January and February) and one rainy (March, April and May). Data were collected through thermohygrometer equipment (HOBO U10), which were allocated on 1.5-meter steel tripods and specific protections for the measuring devices.

After this phase of equipment allocation, the mapping of land use and coverage of measurement points was carried out. To measure the variables at all points of the experiment, a radius of 150m from the location of the collection point, north and west directions (Katzschner et al., 2002) and a radius of 350m in the east and south, in order to obtain the total value of 500 m corresponding to the 0.5 km measure advocated by Oke (2004). This procedure aims to analyze the importance of ventilation as an element of climate control for the thermal field of the area. In this way, the analysis was determined in a total area of 0.21 km² in the vicinity of each analyzed point. The collected data constitute an essential database for the climatic monitoring of the study area.

3. Results and discussions

The Xém-Xém Forest (Figure 2) is where the experimental reference point is located, which is a State Conservation Unit, located in the Bayeux municipality/PB, between the geographical coordinates: Latitude -7.145893, Longitude -34.941287, Longitude South 7 ° 07'29.96 "S, Longitude West 34 ° 55'55.41" W, near João Pessoa. Created by State Decree n. 21262, of February 7, 2000, has a total area of 187 hectares.

Figure 2 - Reference point of the study area Xém-Xém forest.

The occurrence of vegetation, interrupted by the stream called Riacho do Meio, is predominantly composed of individuals from the Atlantic forest, according to SUDEMA, and houses more than 60 types of trees, being a Conservation Unit in an urban environment. This Conservation Unit promotes the protection of native species and the quality of life of the inhabitants of its surroundings, and contributes to the climatic mitigation, soil protection against erosion, as well as the reduction of atmospheric pollution. Figure 3 shows the mapping of the soil cover around the reference point. It is observed in the surroundings of the area that the arboreal vegetation predominates. However, there is also the presence of roofing, herbaceous vegetation, and fragments of pavement, asphalt and sand in smaller amounts.

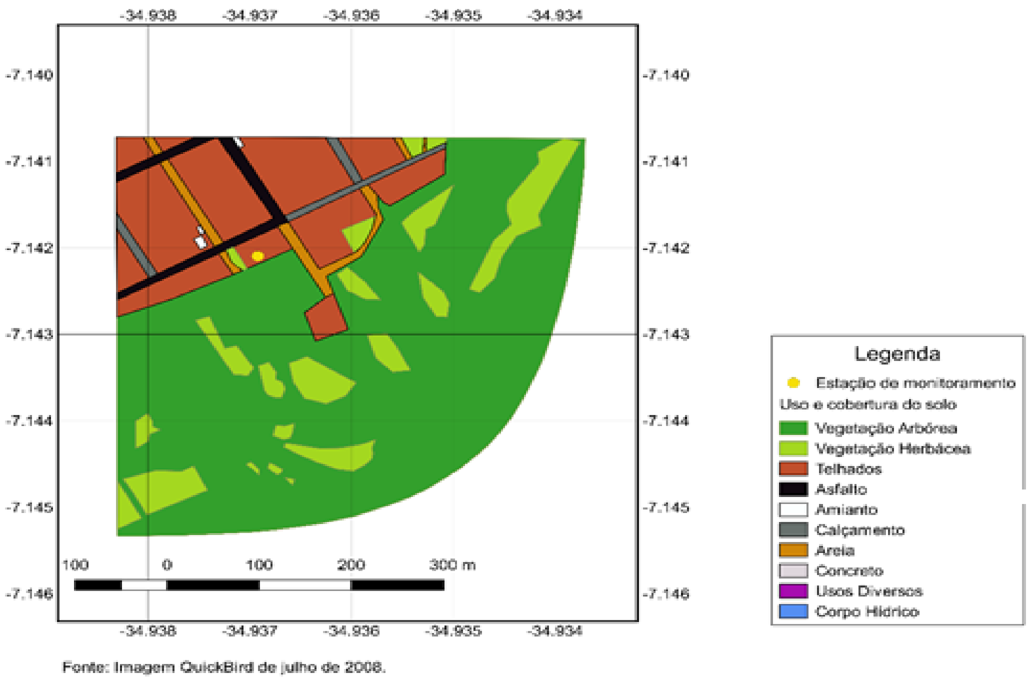

Figure 3 - Land use and occupation - Xém-Xém Forest Source: Santos (2017).

The second experimental point (Figure 4) is located in the Mário Andreazza neighborhood in the Bayeux municipality, between the geographical coordinates: Latitude -7.144273, Longitude -34.927292, Longitude South: 7° 08'39.4 "S Longitude West: 34 ° 55 '38 .2 'W. According to the BIGS (2010), with a population estimated at 9,993, access to the neighborhood is made by BR 230. This sampling point is characterized by its asphaltic and concrete-type soil cover, which contributes to the storage of heat, soil waterproofing, thus influencing the increase in temperature in the study area. The area has a strong concentration of vehicles, which generates emission of polluting gases in the atmosphere. In addition, it is an experimental point with reduced vegetation coverage, which makes it difficult to evapotranspiration, movement of the winds, absorption of pollutants and decrease of temperatures.

Figure 4 - Point located on the banks of BR 230 - Mário Andreazza.

Figure 5 shows the mapping of the soil cover around this experimental sample. The reduction of the vegetal cover and fragments of several types of impermeable materials of covering of the ground is verified. It is observed the predominance of pavement in this experimental sample, which is a positive factor for the formation of urban heat islands. It is possible to also notice the presence of roofs, herbaceous vegetation, asbestos, asphalt, sand and an area attached to the Road Station that serves as a deposit of cars and motorcycles, classified here, as various uses.

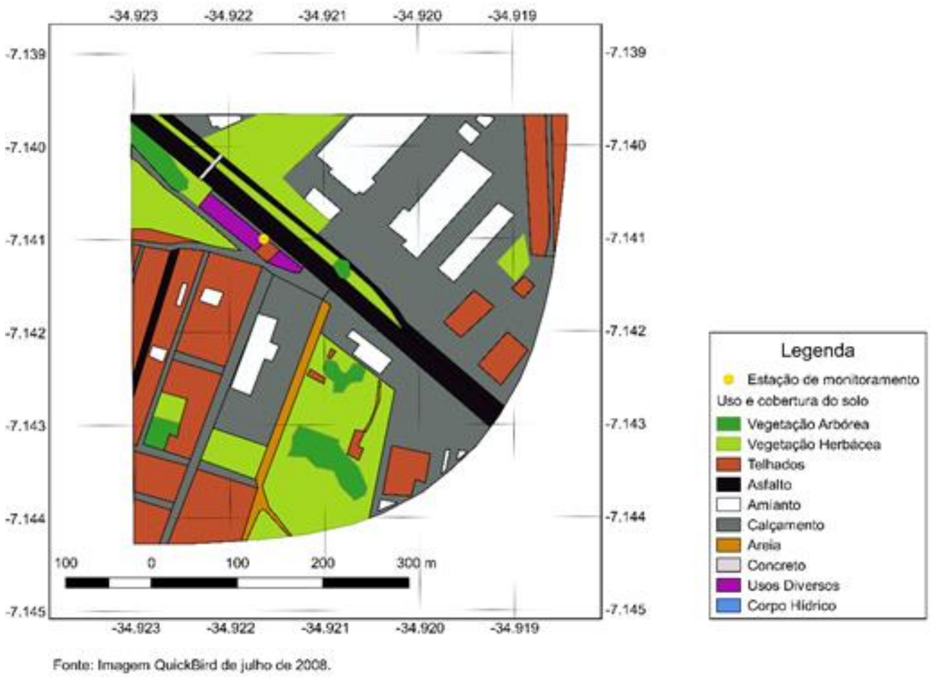

Figure 5 - Characterization of soil types - Mário Andreazza. Source: Santos (2017).

The third point (Figure 6) is located in the Center, northern part of the city of Bayeux / PB. This experimental sample is comprised of reduced vegetation cover, exposed soil and impermeable soil characterized by greater composition of asphalt and concrete. The surrounding area has a strong circulation of vehicles, presence of buildings, pavement and reduction of green areas, which contribute to the increase of air temperature and the formation of urban heat islands.

Figure 6 - Point located in the center of the city of Bayeux.

Figure 7 shows the mapping of the soil cover around the experimental sample located in the center of Bayeux. Herbaceous vegetation cover and arboreal vegetation are not very representative, predominating in this experimental sample, the squabs and footings. The following soil cover materials are also present in this experimental sample: asphalt, sand, asbestos cover and concrete.

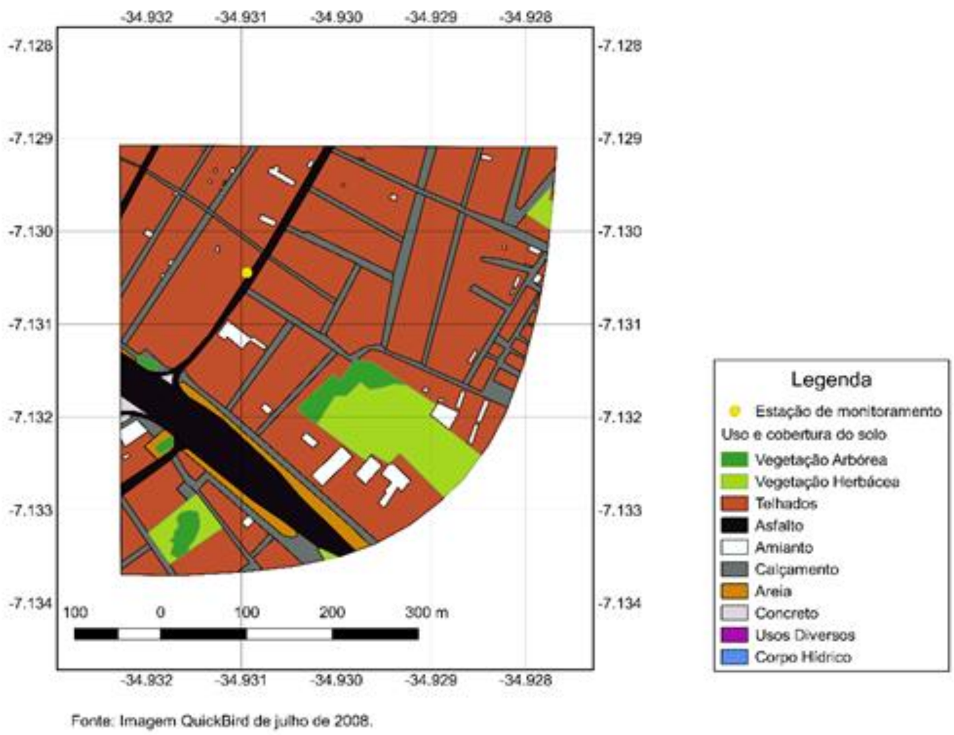

Figure 7 - Characterization of soil types - Center. Source: Santos (2017).

The formation of urban heat islands and their intensity in the study area can be verified in Figures 8 and 9. Figure 8 shows the intensity of the monthly heat island.

For the whole period of microclimatic monitoring, the behavior of the urban heat island during the dry period of the study area - three months of uninterrupted monitoring - showed greater intensity at the experimental point located in the center of the city of Bayeux. Observing Figure 8, it is verified that every month presented positive values for the island of heat that was formed in the center of the city. The heat island evolves throughout the study period at this point. Its thermal amplitude varied between 1.4 °C and 2.2 °C during the months of December and February, respectively.

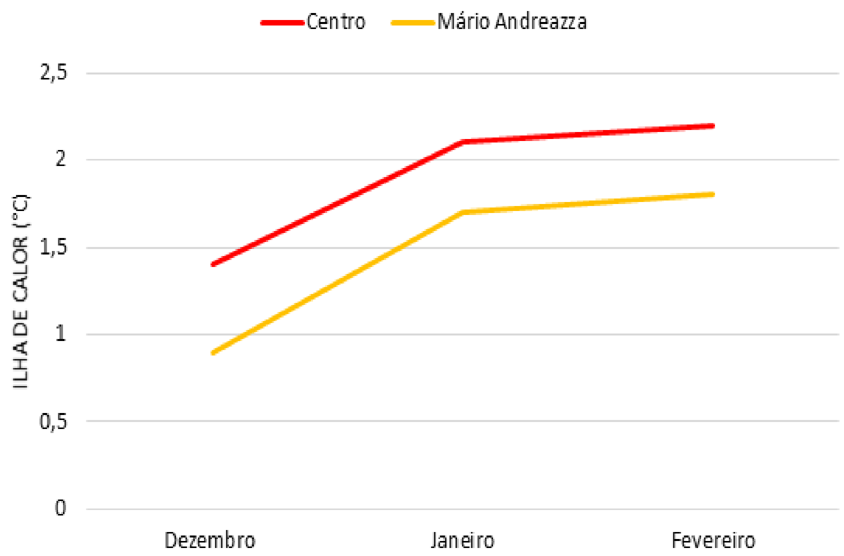

Figure 8 - Monthly Urban Heat Island Intensity.

Thus, there was an oscillation of 0.8 °C between the average of the three months of microclimatic monitoring in the experimental sample located in the city center. The point located in the center of the city of Bayeux \ PB, presents impermeable soil cover, reduced vegetation cover, verticalization and constant vehicle flow. These factors contribute positively to the increase in temperature and consequently to the formation of the urban heat island and thermal discomfort. In a study carried out in the city of João Pessoa, PB Santos (2011) presents similar results for experimental samples that present similar soil cover and use.

The experimental point located in the neighborhood Mario Andreazza also presented positive values throughout the period of microclimatic monitoring carried out in the dry period of the study area. The heat island presented similar behavior to the point located in the center of the city, evolving over the period of analysis. It was verified that the urban heat island in this experimental sample, presented smaller values in relation to the point located in the center of the city. However, their thermal amplitude also ranged from 0.9 °C to 1.8, or 0.8 °C during the three months of monitoring. The point located in the neighborhood Mario Andreazza presents positive factors similar to the point located in the center of the city that favor the formation of urban heat island. However, it is worth noting that the lower flow of vehicles, the lack of verticalization in the neighborhood and the remnants of vegetation cover in the area contributed to the lower intensity of the heat island when compared to the center of the city of Bayeux. Santos (2011) also emphasizes that the most densely urbanized and verticalized areas are those that present positive factors for the formation of the urban heat island at any time of the year. For the author, the environmental characteristics of each experimental sample are much more responsible for the increase in temperature in these areas than the regional climate dynamics.

Figure 9 below shows the behavior of the Heat Island during the weeks of the three months of monitoring for the dry period.

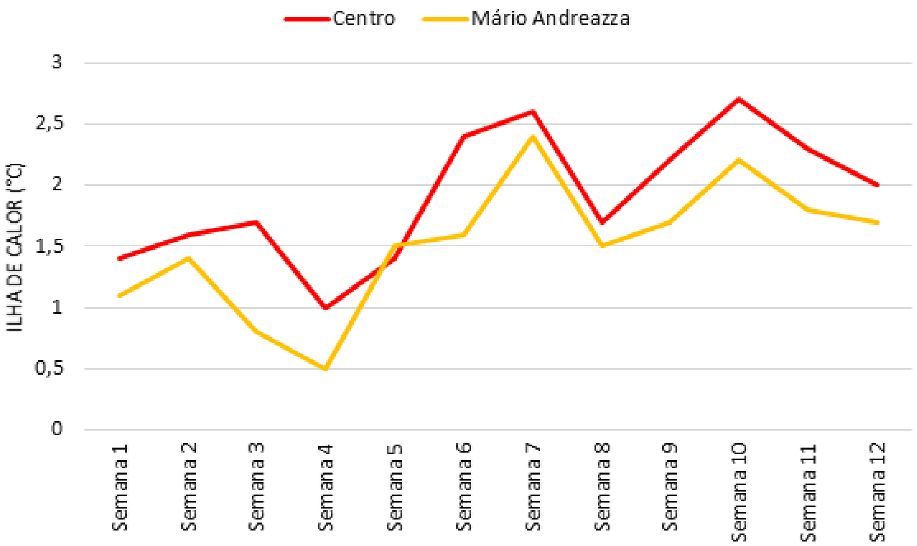

Figure 9 - Intensity of Weekly Urban Heat Island.

Regarding the weekly behavior of the urban heat island in the study area during the three months of microclimatic monitoring, it was again verified that the point located in the center of the city of Bayeux was the one with the highest heat islands.

It was observed that the largest urban heat islands at this point occurred at weeks 7 and 10 of the monitored period with 2.6 °C and 2.7 °C respectively. The lowest heat islands in the same experimental sample occurred at weeks 1 and 4 of the monitored period with 1.0 °C and 1.4 °C, respectively. Thus, it verified a thermal amplitude of the urban heat island varying of 1,7 °C between the twelve weeks of microclimatic monitoring, as observed in Figure 9 for the point located in the center of the city of Bayeux.

At the experimental point located in Mario Andreazza, the heat islands were milder especially in the first weeks of the climate monitoring period. According to data from the State Environmental Superintendence Agency (AESA, 2016), rain was observed during the beginning of the monitored period, which softened the intensity of the heat island in this and other points of the research, ie increasing the relative humidity of the air consequently decreases the ambient temperature, which has influenced the reduction of heat island intensity. The highest heat island intensity at this point was also recorded at weeks 7 and 10 of the monitored period with 2.4 ° C and 2.2 °C, respectively.

The lowest heat islands in the same experimental sample occurred at weeks 3 and 4 of the monitored period with 0.8 °C and 0.5 °C, respectively. Thus, there is a thermal amplitude of the urban heat island varying from 1,9 °C between the twelve weeks of microclimatic monitoring, as observed in Figure 9 for the point located in the neighborhood Mario Andreazza. It is worth noting that the experimental sample located in the center of the city obtained the largest urban heat islands, however, the thermal amplitude of the island of urban heat was higher in the point located in the neighborhood Mario Andreazza.

Houng (1998) emphasizes that the use and occupation of the soil, the presence of impermeable materials and the reduction of green areas are favorable factors for the formation of urban heat islands. This could be observed in the research, since the experimental samples that presented such behaviors corroborate with the statement of Houng (1998).

The heat island formation and its intensity in the rainy season can be seen in Figures 10 and 11. Figure 10 shows the intensity of the monthly heat island. Figure 11 shows the weekly behavior of the heat islands in the rainy season of the region. Regarding the whole period of microclimatic monitoring, the behavior of the urban heat island during the rainy season of the study area - three months of uninterrupted monitoring - was more intense at the experimental point located in the city center of Bayeux/PB. Observing Figure 10, it is verified that every month also presented positive values for the island of heat that formed in the center of the city. The heat island evolves throughout the study period at this point. Its thermal amplitude ranged from 1.5 °C to 1.6 °C during the months of March and May, respectively. Thus, there was an oscillation of 0.1 °C between the mean of three months of microclimatic monitoring in the experimental sample located in the city center. In the face of the properties contained in urban areas such as the types of materials that make up the ground cover - concrete, asphalt, the circulation of vehicles, the little presence of green areas all contribute to an increase in temperature and consequently to the formation of islands of heat. The physical structure of the urban landscape decreases the fraction of the vegetated area and increases the fraction constructed with hard surfaces impermeable to the water contributing to accentuate the temperature difference between the experimental samples (Alder and Colby, 2015, p. 110).

The experimental point located in the neighborhood Mario Andreazza also presented positive values throughout the period of microclimatic monitoring carried out in the rainy period of the study area. The heat island presented similar behavior to the point located in the center of the city, evolving over the period of analysis. It was verified that the urban heat island in this experimental sample, presented smaller values in relation to the point located in the center of the city. However, its thermal amplitude also ranged from 1.4 °C to 1.5 °C, ie 0.1 °C during the three months of monitoring. The point located in the neighborhood Mario Andreazza also presents positive factors similar to the point located in the center of the city that favor the formation of urban heat island. The temperature differences between the points were small and the thermal properties of the soil cover materials favored, even during the rainy season, the increase in temperature and the formation of the urban heat islands. This can be observed at all monitoring points where the reduction of the vegetation cover and the impermeable materials of covering and use of the soil favored the imprisonment of the heat and the formation of the islands of heat.

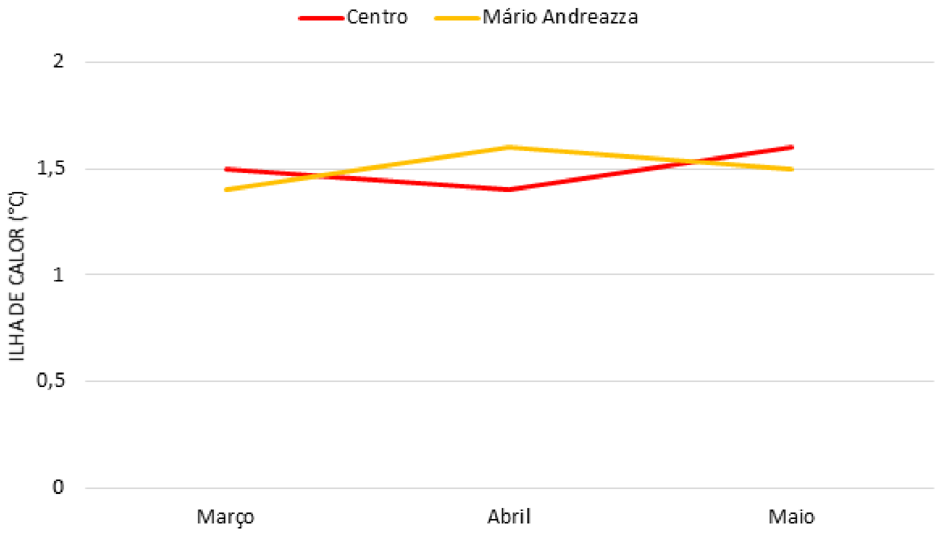

Figure 10 - Intensity of the urban heat island for the entire rainy season.

Observing Figure 11, it was verified that the heat islands with higher temperatures at this point occurred at weeks 10 and 12, and the smaller heat islands in the same experimental sample occurred at weeks 6 and 9. In this way a thermal amplitude of the urban heat island varying from 0.8 among the twelve weeks of microclimatic monitoring. At the experimental point located in Mario Andreazza, the islands of heat were more mild mainly from week 9 in relation to the center of the city. The highest intensities of heat island at this point were recorded at weeks 3 and 9 of the monitored period with 1.8 ° C and 1.9 °C respectively. The smallest heat islands at the Mario Andreazza point occurred at weeks 5 and 10 of the monitored period at 1 °C and 0.5 °C, respectively.

Thus, there is a thermal amplitude varying from 1.5 °C between the twelve weeks of microclimatic monitoring, as observed in the graph for the point located in the Mario Andreazza neighborhood. It is worth noting that the experimental sample located in the center of the city has more frequently obtained the largest heat islands. However, the thermal amplitude of the urban heat island was more intense at the point located in Mario Andreazza. In general, the urban center is warmer than neighboring rural or recreational areas with greater vegetation coverage (Alder and Colby, 2015). One factor that draws attention to this fact is that even during the rainy season, the air temperature remained positive and similar to the dry period of the region, thus forming the urban heat islands in the intra-urban space of the city of Bayeux.

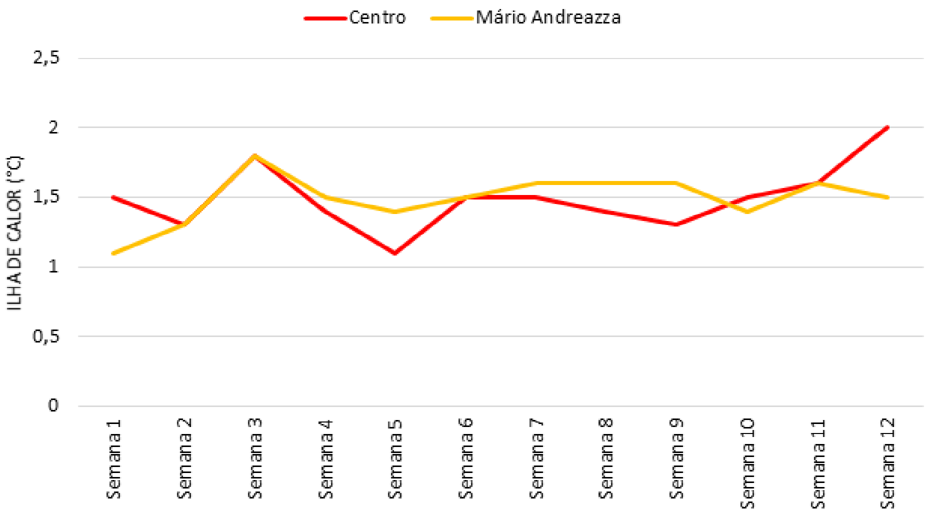

Figure 11 - Intensity of the urban heat island per week in the rainy season.

Comparative analysis of the island of heat in the dry and rainy period of the study area

In the dry period the heat island evolved at the beginning of the whole microclimatic monitoring period for the three months, ranging from 1.4 °C to 2.2 °C with an oscillation of 0.8 °C for the experimental sample located in the center of Bayeux. In the rainy season, this same sample had a heat island of 1.5 to 1.6 °C throughout the entire monitoring period, with oscillation of 0.1 °C. This temperature difference for the two periods amounts to 0.7 ° C in the heat island. The Mário Andreazza point obtained heat island in the dry period ranging from 0.9 °C to 1.8 °C with an oscillation of 0.9 °C. During the rainy season the heat island ranged from 1.4 °C to 1.5 °C throughout the entire monitoring period with oscillation of 0.1 °C. The temperature difference in this sample for the two periods is 0.8 °C in the heat island. For the weekly monitoring in the dry period, the center presented a heat island of 1.4 to 2.0 °C with oscillation of 0,6 °C for the whole weekly period. For the rainy season, this sample presented a heat island varying from 1.5 to 2.0 °C with oscillation of 0.6 ° for the entire microclimatic period. In the weekly analysis of the dry period, the point located in Mário Andreazza presented heat island ranging from 1.1 to 1.7 °C with oscillation of 0.6 ° C, already for the weekly monitoring in the rainy season, this sample experimental study showed heat islands varying from 1.1 to 1.5 °C with oscillation of 0.4 °C. The temperature difference for the heat islands for this sample, for the two monitoring periods, is 0.2 °C. This shows that even in the rainy season of the region, the islands of heat remained positive and in some weeks with results similar to the dry period of the study area. The Table 1 presents the classification of the intensity of the urban heat island for the two periods monitored in the study area: dry and rainy season.

Table 1 - Classification of the magnitude of the urban heat island in the dry and rainy season. Classification adapted from García (1996).

Period	**Point**	**Heat Island**	**Freshness island**	**Classification**
Dry	Centro	2,2	-	Average Magnitude
	Mário Andreazza	0,9	-	Weak Magnitude
Rainy	Centro	1,5	-	Weak Magnitude
	Mário Andreazza	1,4	-	Weak Magnitude

As can be seen in Table, for the dry period there was no presence of freshness island, in the two experimental samples, because in the surroundings of the experimental points there are the presence of impermeable materials, absence of vegetation and ceramic cover, positive factors in the formation of the urban heat island. In the same way, it was observed that in the rainy season no islands of freshness occurred, and that the classification of the island of heat was of low magnitude in the experimental samples. This reflects the presence of rain during this period, which allowed the reduction of heat between the covering materials of the soil that compose the urban area, resulting, in this way, in islands of low magnitude heat. It is verified that even during the rainy season the urban heat islands remained positive with low magnitude and results similar to the dry season heat islands. As previously mentioned, in none of the climatic monitoring periods - dry and rainy - were islands of freshness found. In this way, it can be said that the differentiation of microclimates in the city results from changes in the urban atmosphere caused by the emission of pollutants, industrial activities, deforestation and other anthropogenic activities, generating "islands of heat" and "islands of freshness", according to the interaction of the climate with the configuration and the use of space (Dumke, 2007).

4. Conclusions

The results of the research for analysis of the urban heat island in the city of Bayeux/PB allowed to conclude that:

1. The composition of the constituent materials of the covering of the soil, as well as, the use and occupation in the urban area exert influence on the formation of heat islands. The most urbanized points of the study area present positive factors - impermeable soil cover, reduced vegetation cover, verticalization, vehicle flow - for the formation and intensity of the urban heat island in the study area;

2. The maximum monthly urban heat island intensity for the dry and rainy season was found at the point located in the center of the city of Bayeux. The heat amplitude of the heat island at this point ranged from 1.4 °C to 2.2 °C, ie 0.8 °C, for the dry period and for the rainy season ranged from 1.5 °C to 1 °C, 6 °C, i.e., 0.1 °C. At the point located in the neighborhood Mario Andreazza the intensity of the island of urban monthly heat for the two periods, ranged from 0.9 °C to 1.8, that is, 0.9 °C for the dry season and for the rainy season ranged from 1, 4 °C to 1.5 °C or 0.1 °C;

3. As regards the intensity of the weekly urban heat island, it was found that the point located in the center of the city of Bayeux was the one with the highest heat islands in the two monitoring periods. It was observed that the largest urban heat islands at this point occurred at weeks 7 and 10 of the dry period with 2.6 °C and 2.7 °C and in the rainy season with 1.5 °C and 2.0 °C. Thus, there are positive factors in the soil cover contributing to the formation of heat islands in these samples;

4. At the point located in the Mario Andreazza neighborhood the intensities of the weekly urban heat islands were milder in the first weeks of the dry period and remained constant in the first weeks of the rainy season. The highest intensities of the urban heat islands at this point were recorded at weeks 7 and 10 for the dry period 2.4 °C and 2.2 °C;

5. The maintenance of the green areas and the control of the urban densification, become urgent measures that must be employed in the Urban Planning of the city of Bayeux/PB;

6. Knowledge of changes in the urban thermal field of the study area is indispensable for the maintenance of the quality of life of the population, and may contribute to public policies in the preparation of projects that take into account the sustainable management of these environments.

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