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Analysis of the influence of a green area on its urbanized surroundings in a hot humid climate: a case study in João Pessoa/PB.

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ABSTRACT

Vegetation in a city represents an important strategy for heat mitigation. However, in order to better harness this potential, it is necessary to explore more effective ways to incorporate green areas into the urban fabric and link them to the climate of each location. This study examined the climatic influence of a remnant of Atlantic Forest in João Pessoa, in the northeastern Brazilian state of Paraíba, on the surrounding urban environment, based on monitoring the variables of air temperature and humidity during the winter and summer. The climatic variables were monitored at points along three transects in the vicinity of the forest and at one point inside it, totaling thirteen data collection points. These points were set up on the leeward side of the forest at a distance of 0, 150, 300 and 450 meters from its edge. It was found that the average air temperatures in summer were generally 3°C higher than those in winter, whereas the relative air humidity was about 15% lower. In the two periods studied, the lowest temperatures were recorded at the initial points of each transect, that is, at the edge of the forest, while the highest temperatures were registered at the final points, that is, 450 meters away from the edge. The biggest difference in maximum air temperatures between points was recorded at 1 pm: 3°C in the winter and 2.8°C in the summer. However, it was not possible to identify a gradual rise in temperature due solely to distance from the forest, which indicates the influence of local physical characteristics in the makeup of the microclimate and the importance of distribution of vegetation

Keywords: Urban Climate, Green Areas, Climate Mitigation.

Introduction

The intensification of environmental impacts stemming from local and global climate change represents one of the main challenges faced in the late twentieth and early twenty-first century. It is known that the Earth's climate is dynamic and undergoes constant change, due to natural causes which alter the atmospheric composition. However, human beings, through their activities, intensify this process in an accelerated manner, accentuating global temperatures, primarily through the concentration of gases in the atmosphere that cause the greenhouse effect.

The consequences of global warming in big cities tend to increase with expanding urbanization because, as pointed out by Miller (1976), cities modify the climate, mainly through changes in surfaces, rugosity and atmospheric composition, resulting in higher air temperatures, modification of ventilation, decreased humidity and increased precipitation. Due to lack of adequate environmental planning in cities, there is greater potential for extreme climate situations, such as floods and heat waves.

The use of vegetation in cities, in order to mitigate climate conditions, constitutes an important strategy to prevent the concentration of energy and promote energy efficiency in buildings. According to Gartland (2010), vegetation reduces the formation of urban heat islands, mainly through two factors: shading and evapotranspiration. The shading of urban surfaces helps reduce surface temperature and, consequently, radiant temperature as well. Evapotranspiration, in turn, uses part of the solar energy connected with evaporation. Shading, in particular, is an important strategy for reducing temperature. The ideal solution is when this is provided by vegetation. However, combinations such as shading grassy surfaces through built structures also result in temperature reduction (SHASHUA-BAR ET AL., 2009). In this regard, several studies have been conducted in recent years to explore, quantify and/or recommend more efficient ways to incorporate green areas into urban environments (BARTHOLOMEI, 2003; ABREU, 2008). However, as pointed out by Chang et al (2007), there is little scientific information available regarding the most appropriate ways to harness the climatic benefits provided by these green areas.

The climatic influence of a forest upon its immediate surroundings was studied by Fontes and Debin (2002) in the city of Bauru/Brazil, using hourly mobile measurements from 7 am to 6 pm, at two points within the green area and another seven in its surrounding area. The authors noted that early in the morning there were no major differences between the green area and its surroundings. However, from 9 am on, differences occurred, reaching 2°C between the inner points of the green area and its immediate surroundings, and up to 4°C in relation to the farthest points. It was also found that heat differences in the surfaces resulted in substantial climatic variations, with locations shaded by trees and exposed to local winds presenting lower temperatures.

In Singapore, Yu and Hien (2004) studied the influence of two large green areas, 12 and 36 ha in size, on the surrounding built environment of each one. The collection points were arranged in a linear and equidistant manner, with five points located inside the parks and five points in the urbanized vicinity of the green areas. In the largest park, it was observed that the temperatures inside the park were relatively similar, ranging from 25.2 to 25.5°C, between points 1 and 4. Point 5, on the edge, was slightly warmer, probably due to anthropogenic heat arising from its proximity to the parking lot and highway. In the urban area, there was a gradual warming at the points, indicating that the cooling effect provided by the park is limited.

Ca, Asaeda and Abu (1998) studied the influence of an urban park, approximately 0.6 km2 in size, on its surroundings, in the city of Tama New Town / Japan. Air temperatures recorded inside the park were lower than those recorded in the urbanized surroundings, both during the day and at night. The researchers noted that, at noon, the temperatures registered in the nearby parking lots and commercial areas were more than 2°C higher than the temperature in the park. At the same time, the surface temperature of the lawn in the park was 44.3°C, which was 19°C lower than the temperature of the asphalt and 15°C lower than the concrete. After sunset, the lawn temperature returned to being lower than the air temperature, while the built surfaces remained warmer until late at night. The authors concluded that the green area in question could reduce the air temperature by up to 1.5°C, at noon, in a dense commercial area at a distance of approximately one kilometer in the direction of the ventilation flow.

In the research done by Gomes and Lamberts (2009), in Montes Claros/Brazil, the hygrothermal behavior of green areas was compared to that of built environments. The work centered on the interface between urban climate and urban planning legislation, correlating microclimates to variables related to land use, such as the proportion of green areas, built-up density and urban geometry. As expected, it was found that air temperatures decreased as green areas increased and rose proportionally as impermeable areas increased, albeit these results were more significant at night. In regard to urban variables, for the downtown area, the sky view factor exerted greater influence on nocturnal warming than built-up density, thus demonstrating the importance of urban geometry on heat dissipation.

Duarte and Sierra (2003) correlated, in Cuiabá (Mato Grosso), urban microclimate with certain planning variables that could be regulated through municipal legislation, such as built-up density, tree planting and water surfaces. The results indicated a consistently positive correlation between occupation and land use, on the one hand, and air temperature, on the other, with greater intensity at night. With respect to tree planting and water surfaces, the correlations were negative and seemingly uniform during every schedule that was examined.

The reverse thermal effect, of built surroundings on a green area, was investigated by Figueiró and Netto (2007), in Floresta da Tijuca, Rio de Janeiro/RJ, when studying the influence of built environment on forest edges. The research was based on the assumption that urban pressure in the forest-city interface zone would alter the dynamics of the forest edge effect, changing, in particular, the internal temperature of these areas. Through setting up three mobile transects, temperature and humidity data were recorded, starting at the edge of the forest and then moving inward. It was confirmed that temperatures at the edges of the forest were higher than those inside the forest, with differences of up to 3.5°C in the edge-center transect.

Despite the consensus on the benefits of vegetation, studies aimed at understanding the climatic and urban reality of each site are extremely important, since cities have climatic and formal peculiarities that make it impossible to generalize the results. Along these lines, this research seeks to characterize the influence of a remnant of Atlantic Forest on the climatic conditions of its urbanized surroundings, based on monitoring air temperature and humidity variables. This study was conducted in the Mata do Buraquinho Permanent Preservation Area (forest reserve), located in the heart of the city of João Pessoa, capital of Paraíba, on Brazil's northeast coast, at 7°08'S and 34°53'W. The climate is hot and humid, the daily and annual temperature range variation is low, the average temperature is around 25°C and relative air humidity averages 80% (Atlas of the State of Paraíba apud SILVA, 1999).

Methodology

The urban segment that was studied includes the surroundings located on the leeward side of the green area, comprising north, northwest and west axes, respectively, in the Torre, Jaguaribe and Rangel neighborhoods The definition of the axes was based on the frequency of wind occurrence and distribution, which according to Silva (1999), in João Pessoa, is concentrated mostly in the southeast quadrant between 150° and 180°. Each axis, corresponding to a transect, consisted of four measurement points, equidistant in relation to the forest and non-linear, with the first located at the edge of the forest and the others spaced every 150 meters (0, 150, 300 and 450), totaling twelve points inserted within the urban environment.

A thirteenth data logger was installed within the forest, in order to characterize the climatic behavior of the green area. Data was also used from the meteorological station of Castro Pinto Airport, 8 km away from the site under study.

Temperature and humidity recording devices – ONSET brand, H8 model, with solar protection – were used to collect data at the thirteen measurement points. Figure 1 shows the configuration of the twelve data collections points, distributed along transects A, B and C, in addition to the JB point, located inside the forest.

After establishing the data collection points, the surroundings of each point were characterized, through identifying the main variables of the urban environment, such as built-up density, surface coverings, tree planting and urban

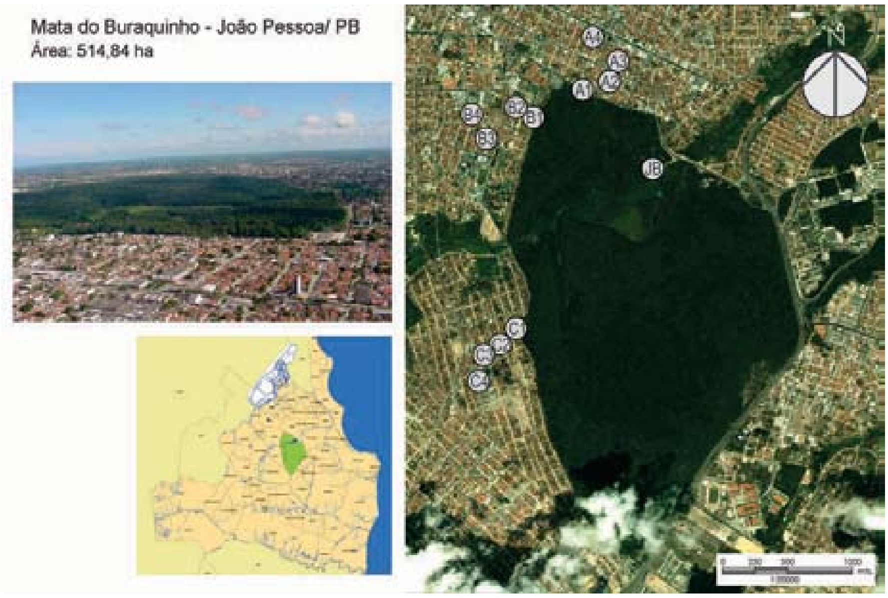


FIGURA 1
Images of Mata do Buraquinho, and to the left indications of the data collection points.

geometry, in order to supply information to understand the behavior of the environmental variables – temperature and relative air humidity – along the transects.

The data collection periods were designed to include periods representing the rainy season as well as the dry season. Data collection during the rainy season was conducted from July 10-30, totaling a sequence of twenty-one days of continuous hourly data. The second data collection period, corresponding to the dry season, occurred from November 9, 2010 to December 10, 2010, recording a sequence of thirty-two days of uninterrupted data.

The treatment and analysis of the data were performed in three stages: a) description of the local physical characteristics of each data collection point; b) comparing the behavior of the hourly temperature and relative air humidity averages between the points in the urban settings, inside the Forest and at Castro Pinto Airport; and c) assessing the behavior of the daily temperature and humidity ranges, simultaneously at all the collection points.

Analysis of the results

Characterization of the data collection points

The characterization of the study area began with an observation of the local terrain. The windward area of the forest is located on a strip between 40 and 50 meters above sea level. Inside the forest, to the north, the terrain slopes downward, reaching a minimum altitude of 10 meters at the Jaguaribe riverbed. Finally, on the leeward side of the forest, where transects A, B and C were installed, the strip once again ranges from 40 to 50 meters above sea level. Transect A is on a strip 40 to 45 meters above sea level, while transects B and C are located on a strip 45 to 50 meters above sea level.

The different transects and their respective data collection points were located in areas with similar occupancy and density. Another criterion for defining the site was the selection of venues with similar morphology and sky view obstruction percentages, as can be seen in Figure 2. In terms of surface materials and finishes, ceramic roofing predominated in the urban environments studied. Within the lots, where the measuring equipment was located, stone floor coverings predominated, at times, interspersed with vegetation or earth. On the other hand, there were differences in the transects with respect to the materials covering the ground on the surrounding streets, which were asphalt, paving stone and earth, in order of importance, in the perimeters demarcating the Torre, Jaguaribe and Rangel neighborhoods.

Figure 3 presents the maps arising from the characterization of the areas in the vicinity of points B1 and C4, which highlight certain local characteristics, such

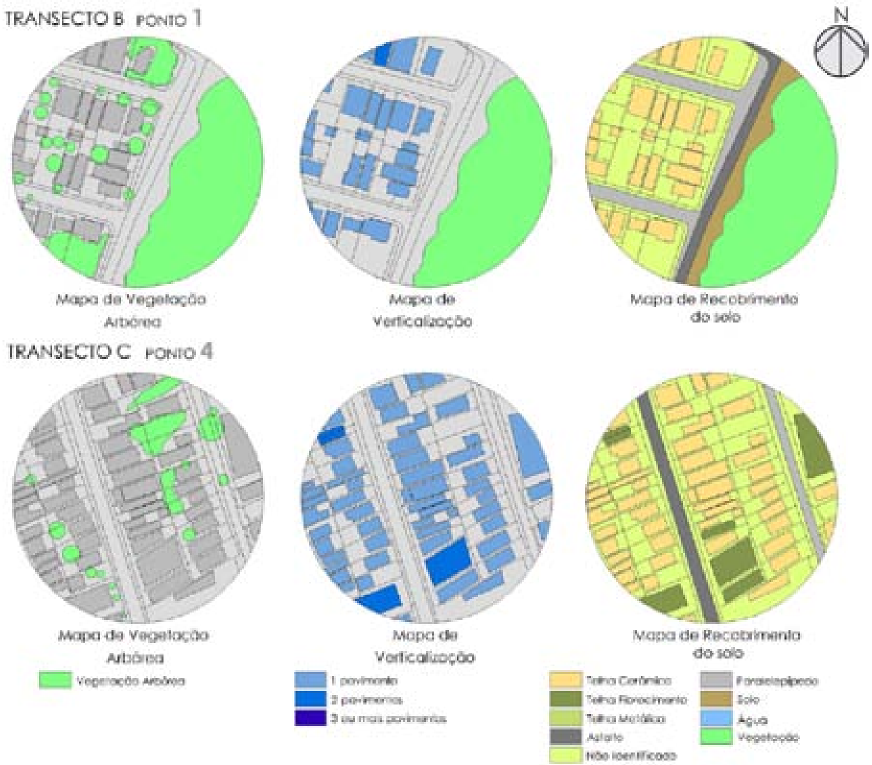
FIGURE 2
Occupation Rate and Sky View Factor (SVF), per collection point.

Ponto	Ocup. (%)	F.C.V (%)
Mata	10	69
A1	19	67
A2	43	68
A3	36	67
A4	38	77

Ponto	Ocup. (%)	F.C.V (%)
B1	16	71
B2	36	69
B3	37	72
B4	30	61

Ponto	Ocup. (%)	F.C.V (%)
C1	25	39
C2	35	81
C3	34	70
C4	38	68

FIGURE 3
Maps showing the physical characterization in the vicinity of the data collection points B1 and C4.



as the presence of tree vegetation, building heights and material covering the ground. At point B1, the first point on transect B, like the other starting points, part of the characterized area is occupied by a strip of forest, unlike the other points that resemble point C4, thus explaining the difference between the values referring to the occupancy rate, as observed in Table 1.

Comparison of temperature and relative air humidity measurements at the urban, forest and airport points

It was initially observed that the daily air temperature and humidity curves were similar in behavior during both data collections periods, with the same minimum and maximum temperature times occurring at 5 am and 1 pm, respectively, while the behavior of the relative air humidity curve was inversely proportional to that of temperature, as expected.

The graph in Figure 4 presents the average daily curves for thermal behavior at the points under study during the winter period. One can note an intense clustering among the curves representing the urban points, indicating a strong similarity in thermal behavior at these points. At 9 am, there is a moderate separation between the temperature curves, which peak in variation at 1 pm, and then once again cluster at 5 pm. At every point, the minimum temperature occurs around 5 am, while the maximum is reached between 12 noon and 1 pm. The air warming cycle begins at 6 am, due to exposure to the sun's rays, and ends at 1 pm, at which point the cooling cycle begins.

As noted earlier, the highest variation between the values recorded in the urban points takes place at 1 pm, with a maximum temperature range of 3°C between the points with the highest and lowest temperatures, C4 and B1, respectively: 30.3°C and 27.3°C, as demonstrated in Figure 4.

Point B1, inserted at the edge of the forest, registered the lowest temperature among the points, manifesting behavior similar to that inside the forest. This point is characterized by the lowest occupancy rate of the set of points and, consequently, the lowest built-up density. It was also noted that in the front area of the lot, where the data logger was installed, there were permeable sections, with shrubs and small-sized trees, in addition to the impermeable stone surfaces. Thus, besides proximity to the forest, other factors, such as built-up density and the presence of vegetation, may have had some bearing on the temperature mitigation registered at this point.

The highest temperature was registered at point C4, located 450 meters from the forest edge and installed in a highly commercial area. This point, when compared with the others, stands out for its accentuated urban characteristics: high built-up density, lower presence of trees and permeable areas and heavy vehicle traffic. As one knows, the above-mentioned elements contribute to heat accumulation in such locations and may exacerbate local weather conditions.

In relation to the daily average relative air humidity curves in the winter period, it can be seen that the different humidity profiles were similar in behavior to each other, reaching their highest level at 6 am and lowest between 12 noon and 1 pm - Figure 7. There was a significant disparity between the curves of the different points, indicating an average variation of ten percentage points, at every measurement time, between locations with high and low relative air humidity. The humidity level of the point situated inside the forest was higher than the set of urban points at each measurement time, only exceeded by the points located at the edge of the forest: A1, B1 and C1. Points C3 and C4 manifested the lowest relative air humidity among the points that were studied.

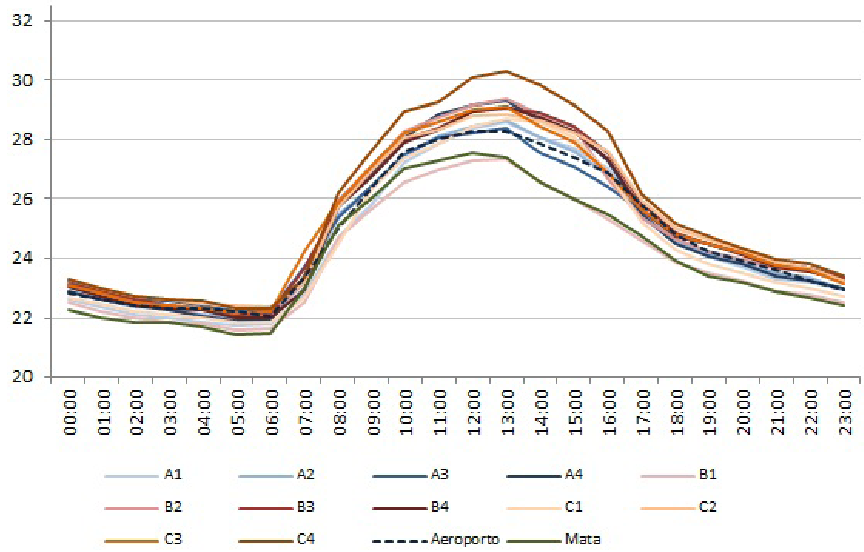


FIGURE 4
Comparison of temperatures between the urban, forest and airport points during the winter period.

As far as the airport, the curve generated from the data collected there is more similar to the curves resulting from the data measured in the urban points. As shown in Figure 4, the average temperature of the point located inside the forest was lower than the airport and other urban points, at every measurement time, with the exception of point B1, which registered the lowest temperature among all the points that were studied. From 1 pm on, the cooling in point B1 and the one in the forest was more intense than the others.

In Figure 5, the average values for temperature and relative air humidity are represented spatially in transects A, B and C, at 5 am and 1 pm, during the winter period. Note the temperature distribution, where the lowest temperatures were generally recorded in the points at the edge of the forest, particularly point B1, which had the lowest temperature of the set – 21.6°C at 5 am and 27.3°C at 1 pm. Point C4, which reached 30.3°C at 1 pm, registered the highest air tempera-

FIGURE 5
Spatial representation of temperature and relative air humidity in transects A, B and C, at 5 am and 1 pm during the winter.

ture of the set of points studied, contributed to by the physical configuration of this site and its immediate surroundings, characterized by the absence of vegetation and permeable areas. It can also be observed that at 5 am there is little difference between temperature extremes – 0.6°C – while the difference at 1 pm is 3°C. With the spatialization of air temperatures, recorded in this study, it was found that temperature did not increase in relation to increased distance from the forest. High temperatures, in some transects, occurred at points next to the forest, as in point B2.

Figure 6 examines the thermal behavior of the air at the collection points during the summer period. It can be noted, in this period, that the temperature curves for the points under analysis displayed higher dispersion in relation to the behavior registered in the winter, during the hours of greater sunlight, from 8 am to 4 pm. In the summer, there was a substantial increase in the maximum and minimum temperatures, accentuating the difference between the thermal behavior of air inside the forest and at the other points, as well as between points, resulting from greater interaction between the physical characteristics of the surroundings, such as solar radiation, especially, and the capacity to absorb, store and dissipate heat. During this period, air temperature behavior fluctuated between 23.7°C and 34°C, while in winter the variation ranged from 21.4°C to 30.3°C.

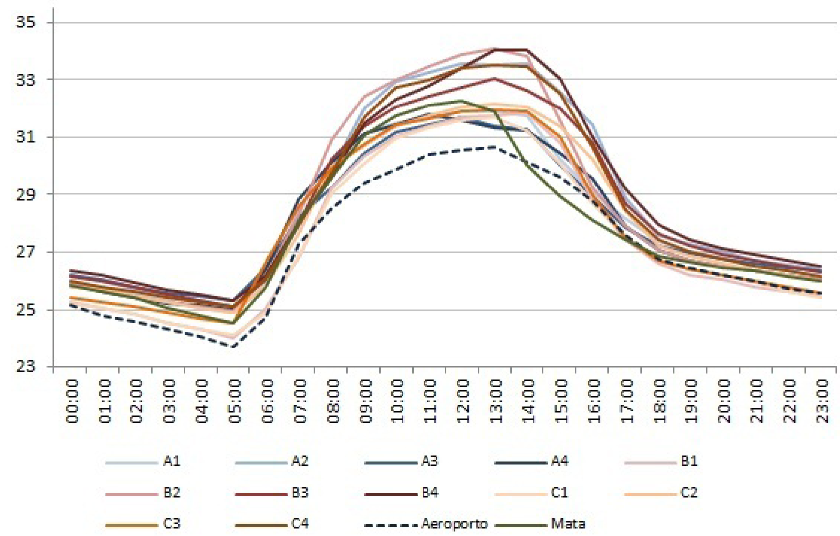
The lowest average temperatures of the points under study were obtained at 5 am, while the highest average temperatures were recorded between 1 pm and 4 pm. The heating and cooling cycle registered the same intervals as in the winter, but with greater intensity. The largest temperature variation among the points occurred at 2 pm, with a maximum temperature range of 4°C, between point B4 and the one inside the forest, at 34°C and 30°C, respectively. Among the urban points, point C1 registered the lowest temperature, at 31.2°C, with a temperature range of 2.8° C, lower than the temperate range obtained in winter.

Point C1, corresponding to the edge of the forest, has morphological characteristics that contribute to heat mitigation. The characteristics with a higher influence include: small tree vegetation, the presence of shrubs scattered in permeable areas close to the sensor and lack of pavement on the adjacent street. However, despite these elements and the lowest sky view factor rate among the set of points, due to obstruction caused by vegetation (approximately 40%), the temperature curve for point C1 was very similar to those of points A1 and B1, also located at the edge of the forest.

Point B4, located 450 meters from the forest, registered the highest temperature of all the points. In addition to distance from the forest's edge, another factor in common with point C4 (point with the highest temperature in winter) is the absence of permeable areas and vegetation within the lot. A unique feature of this point is the ground covering with concrete slabs.

FIGURE 6

Comparison between temperatures in the urban, forest and airport points during the summer period.



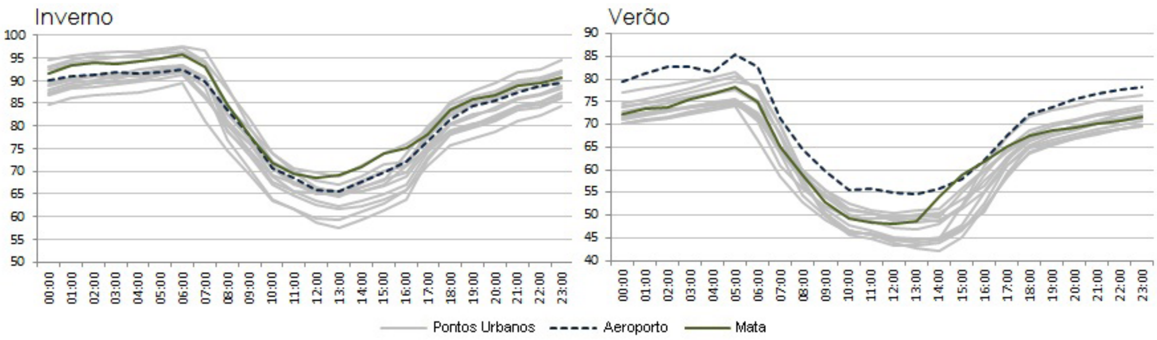


FIGURE 7
Comparison between relative air humidity values in the urban, forest and airport points during the winter and summer periods.

Inside the forest, thermal behavior differed from the other points. Until 12 noon, the temperature curve of the forest occupied an intermediate position within the set of points. However, from 1 pm on, the temperatures recorded in the forest dropped sharply, in a more intense manner fashion than at the other points. When observing the physical characteristics of the site, particularly the sky view factor, it can be noted that this cooling resulted from the obstruction of the sky view, as well as by the shading of the environment, by the surrounding trees, which caused an abrupt interruption of solar radiation at this point.

In the meteorological station at Castro Pinto Airport, the temperatures recorded were below the other points, at every hourly schedule, except during the pe-

FIGURE 8
Spatial representation of temperature and relative air humidity in transects A, B and C, at 5 am and 1 pm during the summer.

riod from 1 pm to 5 pm, when the internal temperature of the forest registered an intense cooling. The expectation was that temperatures inside the forest would constantly be lower than those at the airport. It is believed that the main variable that could influence this behavior is heat mitigation due to ventilation, since the data logging equipment at the Airport is located in an open area at 65 m above sea level, susceptible to the effects of wind, while the research equipment in the Botanical Garden was located in the valley of the Jaguaribe River, at 10 m above sea level and surrounded by trees up to 20 m high, thus blocking the effect of winds and limiting the potential removal of heat by convection. Another variable that may have had a bearing on temperature behavior inside the forest is related to the surroundings. While the measuring equipment in the forest was mounted upon a concrete cover, approximately 3m in diameter, surrounded by bare soil, at the airport, the ground was completely covered with underbrush.

As expected, due to higher temperatures and less rainfall in the months of November and December, the humidity index in the summer data collection period was lower than the winter collection period. The general behavior of relative air humidity varied from 40% to 85% during the summer period, while ranging from 55% to 100% in the winter period, as seen in Figure 7.

In Figure 8, the temperature and relative air humidity values are represented spatially in transects A, B and C, at 5 am and 1 pm during the summer period. During these schedules it can be noted that the lowest air temperatures were registered at the forest edge points of each transect, with the exception of transect A at 1 pm, where the lowest temperature occurred at point A4 and the highest temperature at point A2. Taking into consideration all three transects, the highest air temperature occurred at point B2, which recorded 34.1°C at 1 pm. It was also found that, in summer, the difference between temperature extremes was 1.3°C at 5 am and 2.8°C at 1 pm.

Distribution analysis of the daily temperature range at the different points

During this stage, the main elements that characterize the daily temperature range will be examined. The values in this range refer to the difference between the highest and lowest daily temperature, serving as an indicator of the thermal equilibrium of the site. The distribution of the temperature range values assists in understanding local thermal dynamics, by showing the predominant temperature range value and the variations of these values during the periods studied. Figures 9 and 10 present a summary, using box plots, of daily temperature range behavior at the different collection points during the winter and summer periods.

Figure 9 contains the median values for the set of daily temperature ranges from all the points. The values obtained were around 8°C, with the exception of point B1 which was below the average of the set of points, at only 5.8°C. It can also be seen that the points located 450 meters away from the forest had higher values than the other points of each transect, especially point C4 which obtained the highest temperate range of the set, with 9°C.

Despite the closeness between the median values in the points studied, Figure 9 shows that the daily temperature range at each point is quite irregular, indicating greater fluctuation in daily climatic conditions during this period. The influence of environmental variables, such as ventilation, cloudiness and precipitation, are perceived by observing the difference between the daily ranges recorded at one single point, during the data collection days of the same period. For example, the daily temperature range of point A4 varied between 2.7°C and 11.5°C in winter.

The lowest daily temperature range in the winter period was obtained on July 22, 2010 at all the points, with values ranging from 2.3°C to 3.1°C, much lower

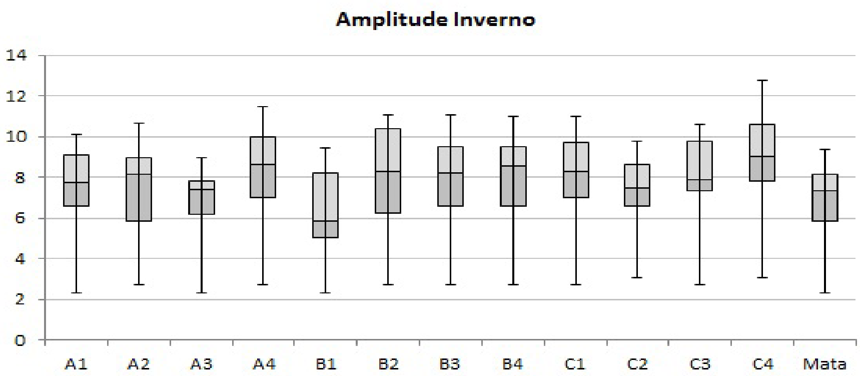


FIGURE 9

Daily temperature range during the winter period.

than on the other collection days, thus indicating an atypical day in the universe analyzed. According to the meteorological data recorded at Castro Pinto Airport, the heaviest rainfall of the winter collection period occurred on this day, and was significantly higher than the other days.

On the other hand, the maximum temperature range values at each point were obtained on different days. Point 4 stands out among the points, which had the highest daily temperature range, of approximately 13°C.

It can be observed in Figure 10 that the main characteristics studied (central tendency, variation and format) are quite different between the points. As for the winter collection period, there was a greater disparity between the maximum, minimum and average values. In the summer, with lower humidity and higher levels of solar radiation, it can be noted that other variables, besides vegetation, are crucial to the composition of the microclimate under study, as compared with the winter period.

There was a great variation between the median values of the set of daily temperature ranges for each point, which varied from 6.8°C in point A3 to 9.9°C in point B2. An important aspect worth mentioning is that no direct relationship was noted between distance from the forest's edge and daily temperature range.

Since the months of November and December are characterized by lower levels of cloudiness and rainfall, there is, during this period, greater uniformity in climate behavior on the days the data was collected. This results in two important behaviors that can be observed in Figure 10. The first refers to the more compact grouping of daily temperature range values, indicating less variation between these values, while the second reveals greater symmetry in the distribution of the daily ranges around the median.

The greatest disparity among temperature ranges, during the summer period, was recorded at the point located inside the forest, while the lowest variation was recorded at point A2, indicating greater similarity between the daily

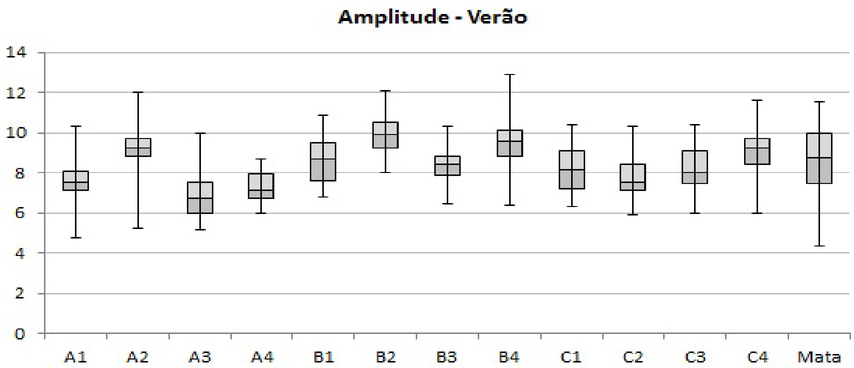


FIGURE 10

Daily temperature range during the summer period.

ranges, despite the marked difference between the maximum and minimum ranges. The highest daily temperature range median was noted in point B2, at 9.9°C. This fact, combined with the high temperature range recorded, can be explained by the physical configuration of the site – as opposed to the other points used in this work, point B2 was a closed space, with little heat mitigation from ventilation. The highest temperatures also occurred at this point.

Conclusions

It can be affirmed that the mitigation of climatic conditions afforded by the forest of Buraquinho essentially occurs in its immediate surroundings, with the greatest effect being noted on its edge. The lowest temperatures were recorded in the initial points of each transect, while the highest were at the end points, with the largest divergence occurring at 1 pm, with 3°C in winter and 2.8°C in summer. On the other hand, a gradual warming of the air temperature along the three transects did not take place – behavior that would demonstrate a direct relationship between temperature mitigation and distance from the forest. It was found that other urban elements have a strong influence on the local climatic context, and can either override or intensify the mitigating effect of the green area, such as susceptibility to wind, the geometry of the location and the thermal characteristics of the materials covering the surfaces.

With respect to the daily temperature range distribution at the measurement points, it can be seen that the range is greater in the winter – the rainy season. In the summer, it is more homogeneous at the urban points, whereas the greatest temperature range was found in the forest. Similar behavior was not observed between the point in the forest and the urban points next to it, barring a few exceptions, notably points A3, B1 and C2 in winter, and in the summer points A2 and B4 have a similar range to the point in the forest.

As distance from the forest edge increases, the characteristics of the urban environment exert greater influence on local thermal behavior. Therefore, a larger distribution of small green areas in the urban environment, when compared with a large concentrated area, should produce a more effective mitigating effect, by increasing the area of forest-city transition, thereby accentuating the effect observed at the edge of the forest.

However, a marked and rapid reduction in vegetation cover is currently taking place in the urban environment of João Pessoa, stemming from the inadequate process of verticalization and land occupation. Backyards and gardens are being replaced by built area and impermeable surfaces. The predominance of individual transport, as opposed to other forms of mobility, has also resulted in the replacement of vegetation in flower beds, streets and squares in order to expand rapid transit routes.

Lastly, the need to preserve the Buraquinho Forest in the city of João Pessoa is vital, due to its importance in maintaining urban environmental quality through its effect on the water-meteorological, physical-chemical and, especially, thermodynamic subsystems, the focus of this research. However, the increasing expansion of impermeable and dense areas tends to negate the effect of green areas, since, as this paper demonstrates, the ability of large green areas to mitigate the micro-climatic conditions of surrounding areas is limited. Expanding this scope can only be accomplished through vegetation distribution, preferably in a uniform manner, over the entire urbanized area.

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