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ORIGINAL

Urban thermal comfort: Mitigation of heat islands in the north-south corridor of 18th and 19th Streets, Pasto

Confort térmico urbano: Mitigación de islas de calor en el corredor norte-sur Calle 18 y 19, Pasto

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ABSTRACT

The study analyzed the presence and magnitude of the urban heat island (UHI) phenomenon in the north-south road corridor of Pasto during the period 2013-2023. Historical records from urban and rural weather stations were used, complemented with direct measurements using a digital thermo-hygrometer at 45 strategic points in the study area. The results showed thermal differences of up to 3,9 °C between urban and rural areas, as well as internal contrasts of 3,7 °C over distances of less than one kilometer. These variations were related to building density, the predominant use of impervious surfaces and low vegetation cover. An upward trend in maximum temperatures and a decrease in minimum temperatures was identified, accompanied by a 24 % reduction in wind speed and a progressive increase in solar radiation. The inverse correlation between temperature and relative humidity, confirmed by a Pearson coefficient of -0,73, showed the importance of vegetation and permeable soils in microclimatic regulation. Sectors with more trees and shade showed cooler and more humid microclimates, while paved areas intensified thermal storage. The mitigation proposal included passive strategies such as strategic tree planting, five-story buildings with staggered morphology, and the use of high albedo and low thermal inertia materials in pavements and roofs. The implementation of these measures reduced the average temperature by 2,76 °C and increased relative humidity by 5,75 %. These interventions demonstrated that sustainable urban planning can improve thermal comfort, reduce areas of discomfort by up to 74 % and provide effective solutions to climate change.

Keywords: Urban Heat Islands; Thermal Comfort; Strategic Tree Planting; Urban Morphology; Reflective Materials.

RESUMEN

El estudio analizó la presencia y magnitud del fenómeno de islas de calor urbanas (ICU) en el corredor vial norte-sur de Pasto durante el periodo 2013-2023. Se emplearon registros históricos de estaciones meteorológicas urbanas y rurales, complementados con mediciones directas mediante un termo-higrómetro digital en 45 puntos estratégicos del área de estudio. Los resultados mostraron diferencias térmicas de hasta 3,9 °C entre zonas urbanas y rurales, así como contrastes internos de 3,7 °C en distancias menores a un kilómetro. Estas variaciones se relacionaron con la densidad edificatoria, el uso predominante de superficies impermeables y la escasa cobertura vegetal. Se identificó una tendencia ascendente en las temperaturas máximas y un descenso en las mínimas, acompañado por una reducción del 24 % en la velocidad del viento y un aumento progresivo de la radiación solar. La correlación inversa entre temperatura y humedad relativa, confirmada con un coeficiente de Pearson de -0,73, evidenció la importancia de la vegetación y los suelos permeables en la regulación microclimática. Sectores con mayor arborización y sombra mostraron microclimas más frescos y húmedos, mientras que áreas pavimentadas intensificaron el almacenamiento térmico.

La propuesta de mitigación contempló estrategias pasivas como arborización estratégica, edificaciones de cinco pisos con morfología escalonada y el uso de materiales de alto albedo y baja inercia térmica en pavimentos y cubiertas. La implementación de estas medidas permitió reducir la temperatura promedio en 2,76 °C y aumentar la humedad relativa en 5,75 %. Estas intervenciones demostraron que la planificación urbana sostenible puede mejorar el confort térmico, reducir áreas de disconfort hasta en un 74 % y aportar soluciones efectivas frente al cambio climático.

Palabras clave: Islas de Calor Urbanas; Confort Térmico; Arborización Estratégica; Morfología Urbana; Materiales Reflectantes.

INTRODUCTION

Godínez et al.[1] mention that Howard was one of the first to notice an excess of artificial heat in cities as a result of anthropogenic changes, building density, and environmental transformation. This would later be called urban heat islands (UHI), a term currently considered one of the most worrying phenomena affecting habitability and thermal comfort. This phenomenon describes the increase in temperature in urbanized areas compared to their nearby rural surroundings, compromising the use of public spaces and the health of inhabitants.

Understanding the phenomenon of UHI requires an interdisciplinary approach that integrates climatic variables, urban morphology, and ecological and environmental aspects. Mitigation strategies include passive solutions that take advantage of natural resources and optimize urban design to improve environmental conditions without relying on mechanical systems and the use of buildings as a component of temperature reduction. Here, urban design plays a fundamental role in mitigating UHI.

In this regard, the north-south road corridor in Pasto, bounded by 18th and 19th streets, represents a significant case study. Its location in the tropical Andes at 2550 meters above sea level, with rugged topography and a colonial urban structure intertwined with modern commercial dynamics, creates particular conditions for the formation of UHI. This axis, with an area of 465 232 m^2, constitutes a commercial and tourist hub within the historic center, characterized by high building density and the predominant use of materials that intensify heat accumulation.

The information used in this study was obtained through field measurements with a digital thermo-hygrometer, applying a capture protocol at points distributed along the road corridor. Secondary data from urban and rural weather stations were also used. The data were organized and processed using statistical tools and simulations in Rhino-Grasshopper (Ladybug), which allowed for the comparison of variables such as temperature, relative humidity, and wind speed in relation to the urban configuration. The analysis of the thermal dynamics of the north-south urban corridor of Pasto reveals significant patterns of climate variation and the presence of the urban heat island (UHI) phenomenon. The data collected over a decade (2013-2023) provides a basis for characterizing these environmental changes and their impact on the urban environment.

The implementation of green infrastructure contributes significantly to reducing surface and air temperatures, while improving the quality of the urban environment. In addition, the use of high-reflectance materials (high albedo), the correct orientation of buildings, and cross ventilation in architectural designs reduce heat accumulation in densely built-up areas; these strategies will be taken into account in the approach and proposal for this corridor.

Analysis of environmental conditions over a decade for the corridor, based on secondary sources. According to Guzmán et al.[2], the study of outdoor comfort addresses a complex mix of relationships between highly variable parameters and includes user groups, activities, and microclimates, i.e., it addresses aspects related to bioclimatic comfort and the effects of adaptation to changes in outdoor environmental conditions. Along these lines, Escobar[3] suggests a method for collecting information on environmental variables; this protocol serves as input throughout this research through non-participant observation, documentary collection, and cartography that identifies the current urban space where the study is being conducted.

Historical meteorological records for the period 2013-2023 from the station located at the CESMAG University headquarters were taken every 5 minutes, allowing for a detailed characterization of climate variations at an intermediate scale in the urban area. The highest maximum temperature was recorded in 2018 with a value of 26,2°C, while the lowest minimum temperature was 6°C in 2022. Analysis of the temperature trend over the decade shows a divergent pattern: while maximum temperatures show an upward trend (with an average increase of 0,15°C), minimum temperatures follow a downward trend (decreasing by 0,21°C annually). In terms of relative humidity, 2022 had the highest average at 79,64 %, while 2016 had the lowest average at 73,46 %. The maximum relative humidity always reached 98 %, but the minimum reached its lowest value (23 %) in 2016.

A particularly alarming finding is the continuous decrease in average wind speed during the study period. The year 2013 recorded the highest speed at 4,50 m/s, while 2023 showed the lowest speed at 3,40 m/s, representing an approximate reduction of 24 % in a decade. This downward trend suggests less air renewal, resulting in greater accumulation of temperature hotspots that negatively affect the thermal comfort of users in urban areas.

In relation to solar radiation, annual averages fluctuated between 6 and 7 kWh/m^2 per day. 2023 was the year with the highest average. The maximum daily values, close to 800 W/m^2, were reached at midday in February, July, and August, while the minimum values (around 400 W/m^2) were observed in the afternoons of April, May, and November. The trend shows a steady increase in solar radiation levels over the decade.

To assess the existence and magnitude of the heat island phenomenon, a comparative analysis was also carried out between the urban station at CESMAG University and a network of stations located in rural areas: Chimayoy (1°15’48.87”N, 77°17’2.64”W), Encano (1°9’34.68”N, 77°9’40.58”W), Botana (1°9’37.69”N, 77°16’44.39”W), and Obonuco (1°12’2.29”N, 77°18’1.63”W). This spatial distribution allowed for a comparative measurement of temperature in different environments.

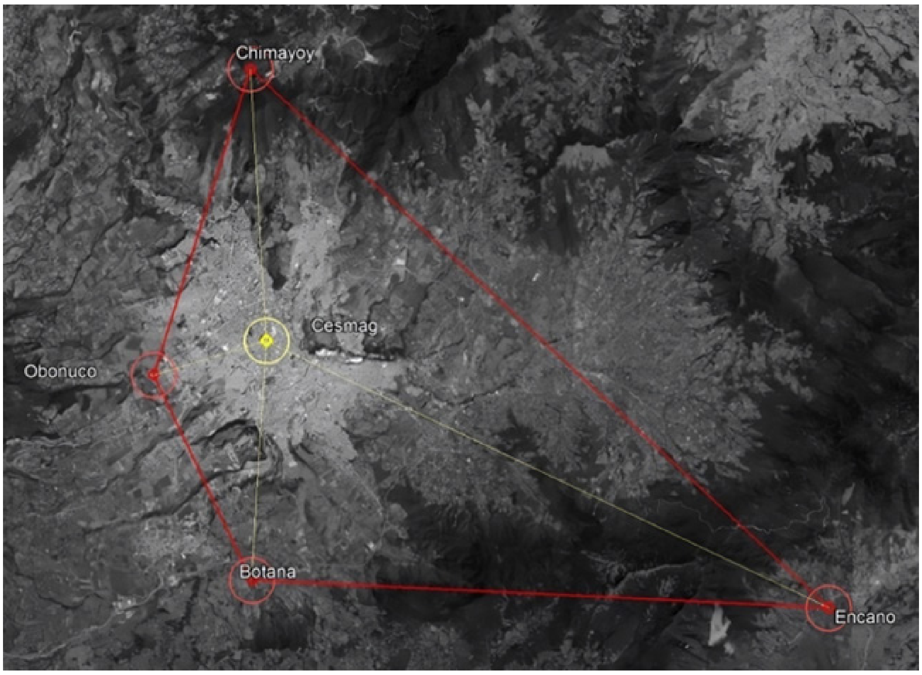


Figure 1. Network of weather stations for comparison of environmental data

The comparison between urban and rural areas shows a significant temperature difference related to the heat island phenomenon as a key component in the increase in urban temperatures. The average maximum temperature recorded at all rural stations was 17,7°C in 2013, while the average minimum reached 8,4°C in 2022. The overall average temperature in the rural station network was 13,2°C, significantly lower than the urban average. The greatest difference was observed in 2016, when annual averages showed an increase of up to 3,9°C in urban areas compared to rural areas. The temperature differential shows that urban areas in Pasto are experiencing a considerable increase in temperature, with a medium to high impact on the local climate.

Analysis of historical data and in situ measurements confirms the presence of the urban heat island phenomenon in the north-south connection of Pasto, with significant temperature differences between urban and rural areas, as well as between areas with different vegetation cover within the same urban corridor. It can be inferred that the phenomenon is related to reduced wind speed, increased solar radiation, and decreased relative humidity, factors that require specific mitigation strategies to improve the thermal comfort and environmental quality of the city. It is important to note that, although heat islands are recurrent, the urban and rural environments of Pasto, taken together, can generate homeostatic processes that allow for some natural temperature regulation. This is due to the influence of the Main Ecological Structure (EEP) on the local microclimate, hence the importance of greening the city.

Analysis of environmental conditions for the corridor, based on primary sources of information

To complement the historical data, a direct measurement protocol was implemented. The methodology included the use of a digital thermo-hygrometer (Ut333 from Unit-t) capable of measuring temperature and humidity in a range of 9 m^2. Forty-five strategic points were selected along the road corridor of 18th and 19th streets. At each point, three consecutive measurements were taken per block, with a total time of 5 minutes for each set, which allowed averages to be calculated and momentary fluctuations to be smoothed out.

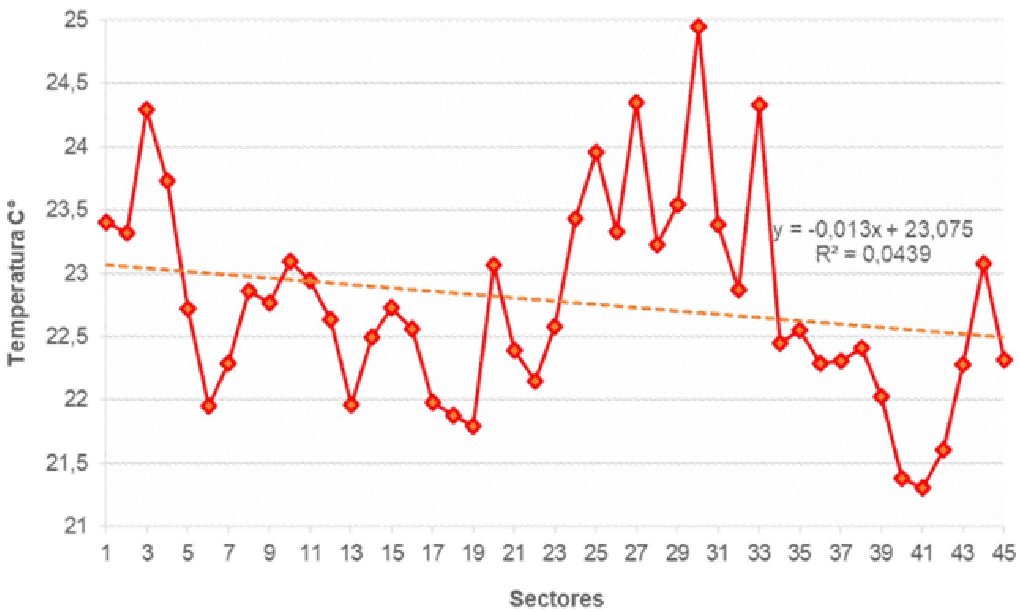
Figure 2. North-South Pasto connection between 18th and 19th Streets, between 19th and 31cth Avenues

The measurements were taken between 12:30 and 1:30 p.m. to capture the period of maximum sun exposure, at a standardized height of one meter above ground level. Both exposed areas and areas under the influence of shade provided by trees were included, allowing for a comparison of different microclimates.

During the measurement period, 450 data points were obtained: 225 for temperature and 225 for relative humidity. The temperatures recorded ranged from a minimum of 21,3 °C to a maximum of 24,5 °C, while the relative humidity values varied from a minimum of 39,4 % to a maximum of 45,4 %. Based on this, the sectors most affected by the ICU were identified and classified into vulnerability categories:

- Low vulnerability: sectors with temperatures below the trend (between 22,5 °C and 23 °C) that have greater thermal regulation.
- Medium vulnerability: sectors with temperatures within the trend range, which show factors that contribute to both the existence and mitigation of the phenomenon.
- High vulnerability: sectors with temperatures above the trend, which are most vulnerable to the increase in the phenomenon.

Sector 30 (18th and 19th streets, between 28th avenue) recorded the highest temperature (25 °C) and lowest relative humidity (39,45 %), while sector 41 (children's playground) had the lowest temperature (21,31 °C) and highest relative humidity (45,41 %). This contrast of 3,69 °C between the two points highlights the relationship between the presence of vegetation, vegetation cover, and temperature. Areas with greater tree cover tend to have cooler and more humid microclimates due to the shading effect and evapotranspiration processes, while areas with less vegetation and a higher proportion of impervious surfaces intensify heat storage, which increases air temperature and reduces relative humidity.



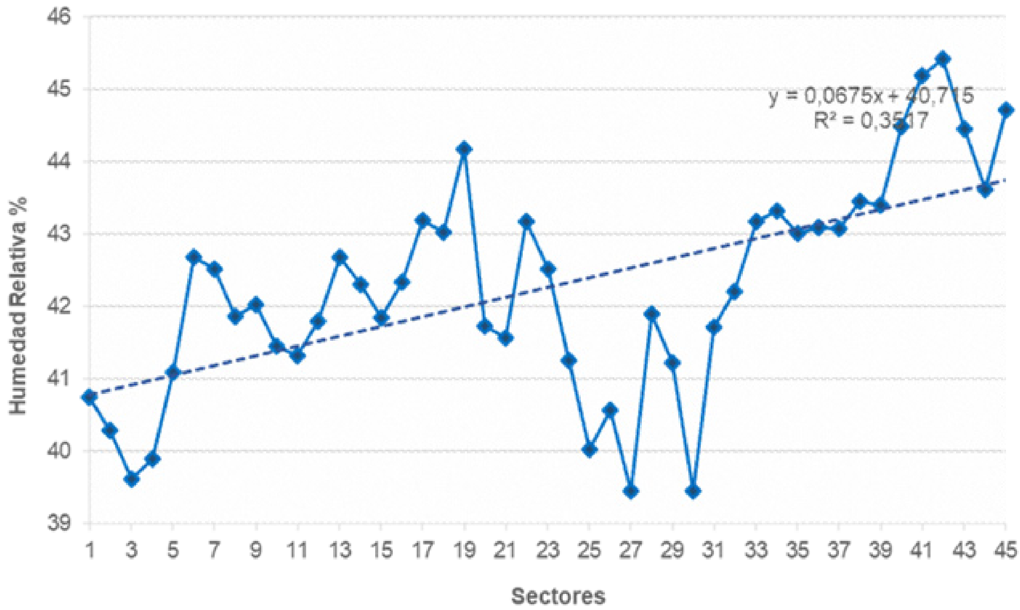


Figure 3. Ambient temperature and relative humidity data on the north-south connection, under measurement protocol

Five urban centers were identified where the temperature exceeds 24,5°C while the relative humidity drops below 40 %. On the other hand, contour analysis revealed thermal propagation axes that follow the main paved roads (Calle 18 between Carreras 26-29), where the urban canyon effect amplifies the heat island phenomenon. There are areas of relative comfort around spaces with significant vegetation, where the temperature can drop by up to 3,7°C compared to nearby paved areas.

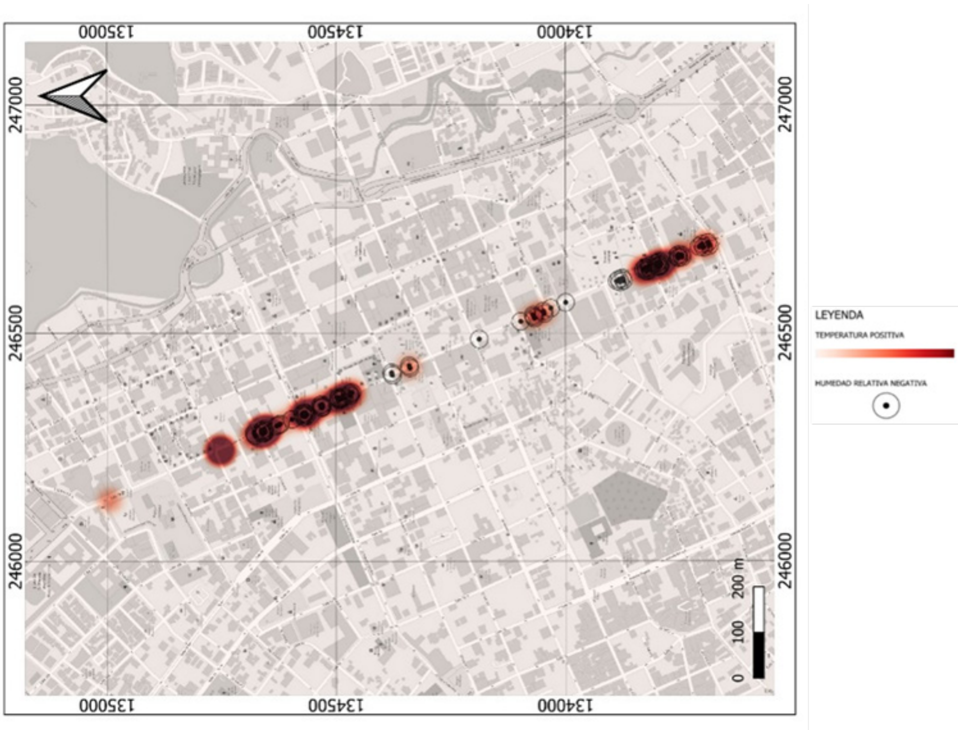


Figure 4. Heat map of high temperature and low relative humidity

The data infer an inversely proportional relationship between temperature and relative humidity: when the temperature increases, the relative humidity decreases, and vice versa. The temperature trend line across the 45 sectors shows a slight decrease (y = -0,013x + 23,075), while relative humidity shows a gradual increase (y = 0,0675x + 40,715). The inverse correlation between temperature and relative humidity is statistically validated by a Pearson coefficient of r = -0,73 (p < 0,001), confirming the hypothesis that the two variables are inversely proportional. In other words, this demonstrates the importance of addressing low humidity to reduce temperature as part of urban heat island mitigation strategies, mainly through the addition of tree components and permeable soils.

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Impermeable surfaces, which occupy 60,24 % of the area studied, act as heat accumulators. Asphalt, with a thermal inertia of 1294 J/m²K, stores six times more heat than permeable soils. Pigmented concrete (1122 J/m²K) and zinc (1329 J/m²K), predominant in facades and roofs, reflect only 25-35 % of incident radiation, compared to 60 % reflected by experimental cool roofs.

The colonial layout with 100x100 m blocks and continuous facades creates urban canyons that alter ventilation dynamics. 3D simulations showed that the 5-story buildings in the PEMP sector cast only 2,41 % useful shade at midday, while in unregulated areas, the combination of irregular heights generates turbulence that stagnates masses of hot air.

The topographic slope (15 m over a length of 500 m) creates an effect where the lower areas (2,519 m above sea level) accumulate 1,7°C more than the higher areas (2,534 m above sea level) due to the nocturnal drainage of cold air. This phenomenon is intensified by commercial activity (ovens, vehicles), which adds an additional 0,8°C during peak hours.

The normal distribution (Gaussian bell curve) showed that there is a 14,94 % probability that the temperature will exceed the limits established for the comfort range according to the Olgyay model. This probabilistic approach made it possible to categorize the sectors analyzed according to their level of thermal risk. Sectors with severe thermal risk stand out, located on the section of Calle 18 between Carreras 27 and 29, characterized by surfaces with high thermal inertia and sparse vegetation, with probabilities of comfort areas of 30,56 %, 30,77 %, and 25,45 %.

Sectors with moderate thermal risk have a 10-25 % probability, where the combination of urban factors generates occasional discomfort. There are also sectors with low thermal risk (less than 10 % probability), characterized by the presence of vegetation that helps maintain conditions closer to thermal comfort. This probabilistic segmentation allows urban interventions to be prioritized according to the level of thermal risk in each sector, optimizing the allocation of resources for mitigation strategies. Areas with high temperatures and low humidity significantly increase thermal stress in public spaces.

In addition, the spatial correlation between both variables was classified according to their combined bioclimatic behavior, applying Olgyay's thermodynamic comfort principle. Analysis of Olgyay's diagram reveals that 37,8 % of the urban spaces evaluated are outside the comfort zone during the critical period of the day, requiring specific mitigation strategies.

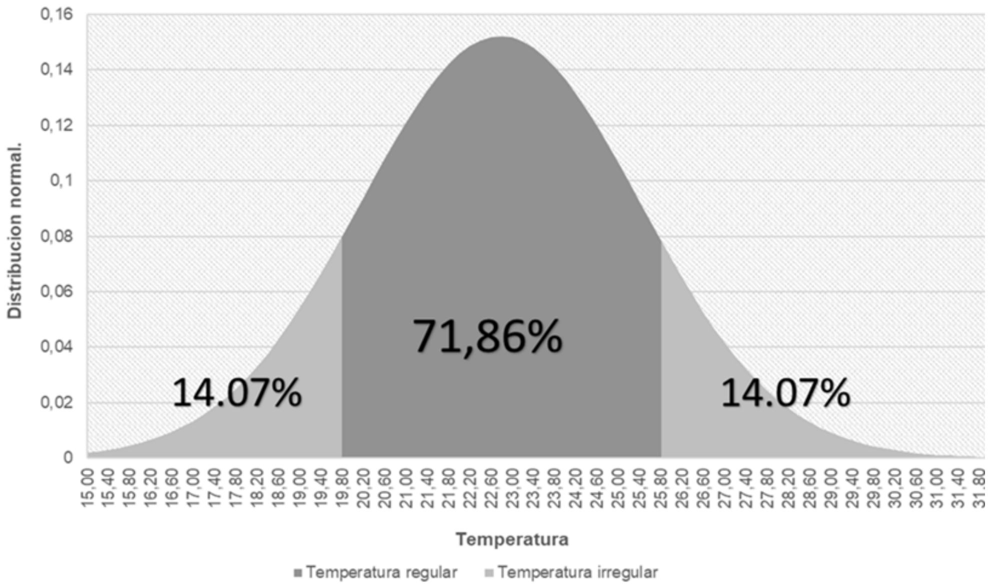

Figure 5. Gaussian bell curve, probability of comfort or discomfort areas for temperature

Spatial analysis of the thermal distribution in the study area identified critical sectors with higher levels of thermal stress, mainly associated with low vegetation cover, high density of impervious surfaces, and absence of shade elements, passive strategies that will be taken into account for the mitigation of UCI. In this context, it is necessary to formulate strategies that integrate urban design solutions and criteria aimed at reducing high temperatures and improving local environmental conditions.

With the integrated implementation of strategies, it was determined that the temperature reduction is up to 4,2°C in the most critical sectors for urban thermal regulation, which shifts the probability distribution toward ranges of greater thermal comfort and reduces the percentage of areas outside the comfort zone from the current 14,94 % to an estimated 3,8 %. The projected strategies are:

Strategic tree planting

Trees play a fundamental role in modifying urban air currents. The linear arrangement of trees along streets and sidewalks acts as a partial barrier to air flow, generating turbulence that improves the dispersion of pollutants and contributes to surface cooling through the shade they cast. In squares and parks, tree masses create differentiated microclimates with reduced wind speeds and areas of relative calm, which improve air mixing and increase environmental humidity. Evapotranspiration from trees adds water vapor to the surrounding air, increasing relative humidity and reducing the perceived temperature, with a natural cooling effect that extends to adjacent areas, especially at night. In their research on the impact of tree planting in Barranquilla, Colombia, Zuluaga Gómez et al.[4] demonstrated that planting trees in public spaces can drastically reduce operating temperatures, mitigating the heat island effect by 63 % with the inclusion of 50 trees along the road.

The efficiency of canopy height is also a determining factor in urban tree planting. Trees with low canopies (zero trunk height) are 47,45 % more effective than those with medium canopies and 50,57 % more effective than those with high canopies in terms of shade projection and thermal reduction.

Practical application in urban environments requires consideration of the functionality of spaces on sidewalks and pedestrian walkways. The research results suggest maintaining a minimum trunk height of more than 2,6 meters to ensure the smooth flow of pedestrians and not obstruct the field of vision of passersby. This configuration allows for temperature reductions of up to 4°C through effective shade projection. Regarding optimal tree density, simulations showed that the most efficient distribution was 25 % coverage with trees covering an area of 64 m^2 and low canopies, which was 38,93 % more effective than the tree configuration with medium canopies and 44,95 % more effective than that with high canopies. The proposed distribution optimizes available resources and avoids visual saturation in urban spaces by maintaining a balance between tree intervention and the functionality of the spaces.

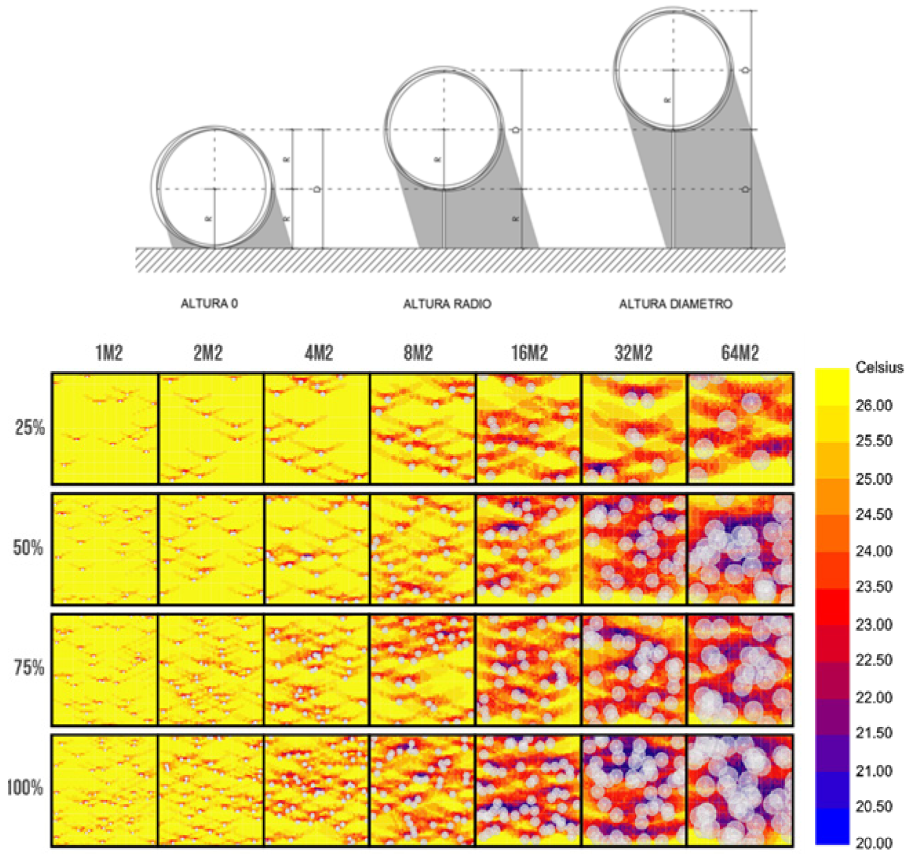

Figure 6. Plant material heights and vegetation cover effectiveness on shade projection vs. tree density

The optimal distance between trees corresponds to the radius of their canopy, creating an aligned arrangement that maximizes the efficiency of the projected shade. With this configuration, the low canopy proved to be 56 % more effective than the medium canopy and 58 % more effective than the high canopy in terms of cumulative thermal reduction. A specific simulation in sector 3 of the study area showed that the implementation of 95 additional trees, strategically arranged according to these criteria, generated a significant reduction in temperature, substantially improving the thermal comfort of the public space.

On streets, pedestrian walkways, and sidewalks, where traffic and visibility are priorities, it is recommended

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to maintain a minimum trunk height of 2,6 meters with a crown diameter of less than 2,6 meters, while on pedestrian walkways the crown can extend up to 3,19 meters. In contrast, for squares, parks, and plazas, where there is greater spatial availability, a crown diameter of up to 8,99 meters is suggested, measures that make the most of the shade projection capacity without compromising the functionality of the public space.

Table 1. Matrix of relationships by function between dimensions by diameter, area, and different urban sections

Diameter (m)	Compatibility of tree diameter in relation to urban space							Area-M2
	Streets	Pedestrian	Sidewalks	Front gardens	Small squares	Squares	Parks	
1,13	X	X	X	X	X	X	X	1
1,6	X	X	X	X	X	X	X	2
2,26	X	X	X	X	X	X	X	4
3,19	--	X	--	--	X	X	X	8
4,51	--	--	--	--	X	X	X	16
6,38	--	--	--	--	--	X	X	32
8,99	--	--	--	--	--	X	X	64

Optimization of urban morphology

Morphological analysis of buildings revealed that five-story structures (approximately 15 meters high) achieve an optimal balance in generating efficient shade over urban spaces. This configuration demonstrated up to 15 % superiority in thermal reduction efficiency compared to other heights evaluated. Structures of this height generate dynamic shading patterns that cover approximately 64 % of adjacent pedestrian areas without completely blocking the wind currents necessary for natural ventilation, resulting in an overall improvement in urban thermal comfort.

It is accompanied by an optimized volumetric configuration where the first floor remains aligned with the facade, the second floor is set back one meter, the third floor incorporates a 0,5-meter cantilever, the fourth floor is set back another meter, and the fifth floor resumes a 0,5-meter cantilever. The strategic volumetric variation proved to be up to 25 % more efficient in terms of thermal reduction than traditional building configurations.

The complementary incorporation of specific architectural elements or integrated vegetation on the facades enhances these benefits and reduces thermal inefficiency by up to 30 %, which is equivalent to a significant temperature reduction of 3,2°C in the immediate microclimate. Strategic overhangs and recesses not only cast shade, but also generate convective currents that improve air flows at pedestrian level and contribute decisively to the overall thermal comfort of the urban space.

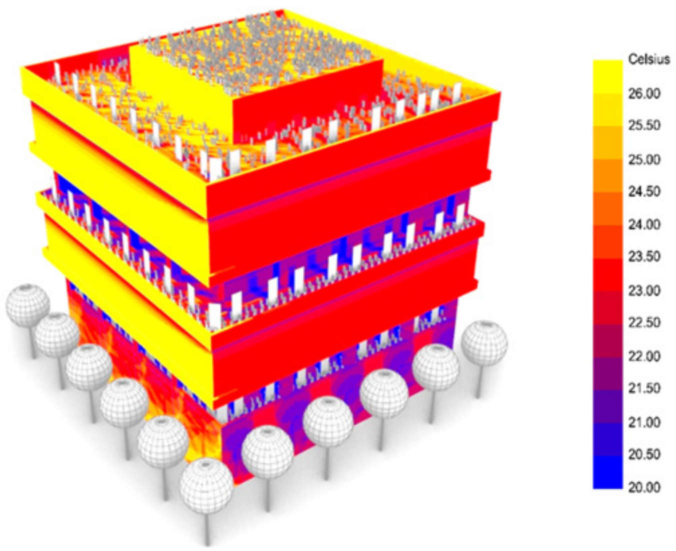

Figure 7. Most efficient volumetric model in terms of casting shade on itself

Materials with high albedo and low thermal inertia

Galvez Salinas[5] determines a close correlation between the type of material and its physical properties. He concludes that the urban heat island is a phenomenon that occurs in urban and suburban areas as a result of

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the use of materials with a high capacity for absorbing and retaining solar heat (albedo), far superior to that of natural materials or less developed rural areas.

The surface composition of the corridor showed that 60,24 % corresponds to impermeable surfaces, mainly asphalt and concrete. These materials, with high thermal inertia, function as efficient daytime heat accumulators and nighttime emitters, contributing to the unfavorable thermal cycle.[6]

Asphalt, as the main material, stores approximately six times more heat than natural permeable soils. For example, this becomes evident when comparing the Children's Park, with 31,7 % tree cover, which maintained temperatures of 21,3°C, compared to 25°C recorded in the Carrera 28 sector, characterized by continuous concrete and asphalt surfaces. The difference of 3,7°C in just 800 linear meters confirms the impact of materials on the formation of differentiated microclimates. Each 10 % increase in impervious surface area is associated with a 0,8°C increase in ambient temperature.[7]

The strategic selection of materials for urban spaces is a fundamental pillar in the effective mitigation of heat islands. Green areas with medium-height grass demonstrated excellent thermal properties, offering high evapotranspiration, low thermal inertia (value of 400), and moderate albedo (20 %), achieving a temperature reduction of 3,5°C. Light-colored paving stones, with medium thermal inertia (2000) and albedo of 35 %, achieve a temperature reduction of 1,5°C.[8] Permeable concrete, characterized by thermal inertia of 1,800 and albedo of 35 %, reduces the ambient temperature by 2°C. Rigid concrete pigmented with specific additives to increase reflectance showed the greatest temperature reduction among the pavements analyzed (2,5°C), and stands out as an efficient alternative for high-traffic areas.[9]

Table 2. Materials proposed for temperature reduction in the corridor

Proposed Material	Thermal Inertia	% Albedo	Temperature Reduction
Use in urban spaces			
Rigid concrete pigmented with reflectance-enhancing additives	22 000	45	2,5
Permeable asphalt	1200	25	1,5
Light-colored cobblestones	2000	35	1,5
Green area	400	20	3,5
White cobblestones	2000	45	2
Permeable concrete	1800	35	2
Use on building roofs			
Light-colored, reflective concrete	2200	45	2
Green roofs	800	25	3
Cool roofs	1000	60	3,5
Tile with additive on reflective surface	1400	45	3
Green roofs	800	25	3,5
Green roofs	800	25	3,5
Permeable concrete	1800	35	2
Green area	400	20	3,5

For building roofs, where sun exposure is highest, cool roofs with relatively low thermal inertia (1000) and exceptionally high albedo (60 %) achieve a significant reduction of 3,5°C. Green roofs, characterized by low thermal inertia (800) and moderate albedo (25 %), reduce the temperature by 3°C and provide ecosystem benefits such as rainwater retention and improved urban biodiversity. The strategic replacement of conventional roofing materials achieved thermal reductions of up to 3,5°C, particularly notable in areas outside the PEMP (Special Management and Protection Plan), where heritage restrictions are less strict and allow for more extensive interventions.

The transition to materials with lower thermal absorption capacity and greater permeability in building roofs resulted in a significant reduction in accumulated temperature, especially noticeable in areas with high sun exposure. In public areas, the proposed measures focused on hexagonal paving stones with grass in squares and permeable pavements in streets, while sidewalks incorporated highly reflective paving stones complemented by strategic tree planting, forming an integrated thermal mitigation system that optimizes the thermal behavior of the urban complex.

The coordinated and comprehensive proposal of these passive mitigation strategies succeeded in reducing the average temperature from 22,78°C to 20,02°C along the north-south connection, representing an overall decrease of 2,76°C. The reduction was achieved through the strategic combination of approximately 1,533 trees located according to criteria of maximum thermal efficiency and the widespread implementation of materials characterized by high albedo and low thermal inertia in pavements and building roofs.

Passive mitigation strategies fully respect the pre-existing urban structure and functionality by preserving the original dimensions of public spaces, sidewalks, and streets, which facilitates their implementation without affecting mobility or established uses. Strategic tree planting not only provides effective shade on the most exposed surfaces, but also promotes urban biodiversity, improves air quality by capturing polluting particles, and creates more attractive spaces that encourage social interaction and active use of public space.

Interventions based on bioclimatic principles for urban thermal comfort, combined with scientifically based selection of urban materials, can generate measurable positive impacts on the microclimate without compromising the essential functionality of existing urban spaces, and set a precedent for sustainable urban planning. In terms of temperature, the proposal generates an average thermal reduction of 3.° C compared to current conditions, demonstrating its effectiveness in mitigating the heat effect in the sectors evaluated. The temperature with the proposed reduction remains between 18,5° C and 21,5° C, with an average close to 20° C.

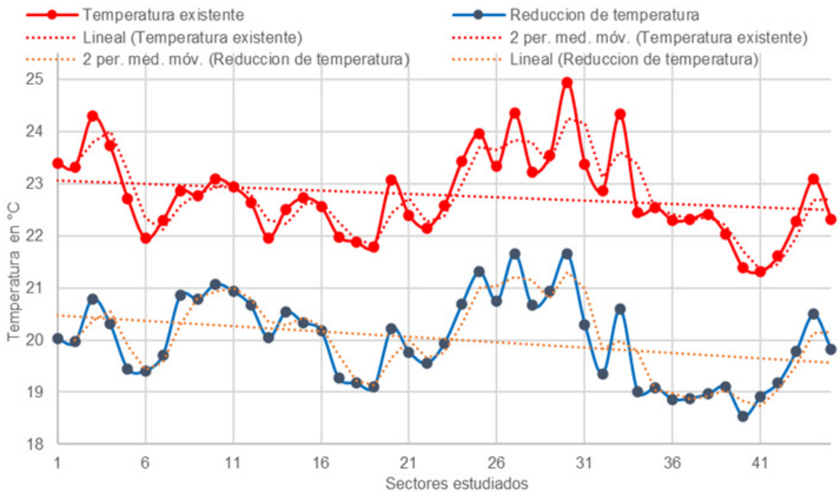

Figure 8. Relationship between temperature measured in the field and reduction through passive mitigation strategies

A complementary phenomenon of great relevance to urban thermal comfort was also observed: an average increase of 5,75 % in relative humidity (from 42,27 % to 48,01 %), a direct consequence of the increased evapotranspiration generated by the introduced vegetation and the permeable materials implemented. This increase in relative humidity contributes significantly to perceived thermal comfort, as it acts as a natural regulator of the thermal sensation in open urban spaces.

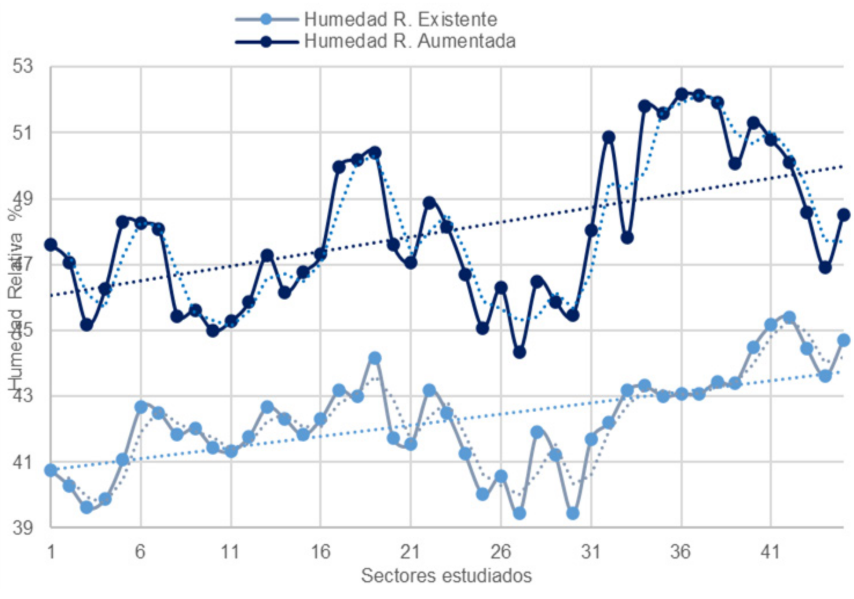

Figure 9. Relationship between relative humidity measured in the field and increase through passive mitigation strategies

CONCLUSIONS

The urban heat island (UHI) phenomenon in the north-south corridor of the city of Pasto presents thermal differences with contrasts of up to 3,9°C (° °C) between urban and rural areas, and internal variations of up to 3,7°C (° °C) at distances of less than 800 meters. This marked thermal heterogeneity highlights the decisive impact of urban morphology and surface composition—such as the type of coverage, building density, and the presence of vegetation—on the thermal behavior of the built environment.

In response to this problem, an intervention based on passive climate mitigation strategies was proposed, which have a significant impact on reducing the average temperature and increasing relative humidity without compromising urban functionality. The combination of strategic tree planting (25 % tree density), five-story buildings with staggered volumes, and the use of high-albedo, low-thermal-inertia materials reduced the urban area exposed to thermal discomfort by 74 %.

From a microclimatic point of view, the data show an average temperature reduction of close to 3-° C in the areas where interventions were carried out, compared to the values existing before the proposal. This temperature decrease is accompanied by an increase in relative humidity, whose inverse correlation with temperature confirms the effectiveness of strategies that prioritize evaporative cooling and environmental moisture retention. The results are relevant in high-altitude contexts such as Pasto, where equatorial conditions enhance the thermal sensitivity of the built environment.

Overall, the application of integrated passive solutions not only mitigates the ICU phenomenon, but also improves thermal comfort and urban livability, and provides validated tools for sustainable urban planning in the face of the challenges of climate change.

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FINANCING

None.

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

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