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The Influence of Vegetation Cover on Temperature and Humidity Distribution Affecting Thermal Comfort

Firnawati[1*], Umara Hasmarani Rizqiyah[2], Muh. Aryanugraha Ismajaya[3], Andi Firman Muhibuddin[4]
State University of Makassar
Corresponding Author: Firnawati; firnawati@unm.ac.id

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A B S T R A C T

Vegetation plays a crucial role in improving the microclimate of an area, particularly through tree canopy cover. This research aims to examine the influence of tree canopy coverage on air temperature and humidity within a landscape site. A quantitative approach was employed by directly measuring temperature and humidity under tree canopies and in open areas, along with regression analysis to assess the relationship between variables. The results show a significant difference in temperature and humidity between shaded and unshaded areas. The wider the canopy cover, the lower the temperature and the higher the humidity. The correlation between canopy coverage and temperature was -0.2494, and with humidity, it was 0.2174. Isotherm and isohygro maps revealed spatial patterns that support these findings. These results indicate that tree canopies contribute positively to thermal comfort and should be a primary consideration in climate-responsive landscape planning

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INTRODUCTION

Human interaction with the landscape is mediated by various sensory experiences such as form, texture, color, aroma, sound, and light (Shuoxian, 2024). These elements interact to create a sense of harmony within a space, where order, dynamism, and diversity contribute to a balanced and supportive environment (Xu, Zhao, Jin, Zhu, & Chai, 2025). Such harmony is not only visual or physical but also emotional and perceptual, creating spaces that are comfortable and welcoming for human activity (Alwah, et al., 2024). Comfort, as an intangible aspect of landscape design, plays a crucial role in ensuring that outdoor spaces can accommodate a range of human needs and behaviors (Tongyun, Wei, & Fei, 2024). Comfort can be classified into several dimensions, including climatological, psychological, and auditory. Each dimension is shaped by both natural and designed elements in the landscape, and understanding these dimensions is vital to enhancing the quality of outdoor environments (Stoltz & Grahn, 2021).

Among the various forms of comfort, climatological comfort is especially significant in tropical countries like Indonesia (Senjaya, Eni, & Sudarwani, 2025). Due to its hot and humid climate, Indonesia faces challenges related to thermal conditions in outdoor spaces (Handayani, Murtyas, Wijayanta, & Hagishima, 2024). Ensuring a thermally comfortable environment is essential to promote the usability and attractiveness of green public areas.

LITERATURE REVIEW

Vegetation and Climatological Comfort

Climatological comfort is primarily influenced by key atmospheric elements, such as air temperature, relative humidity, and wind speed (Zhou, Zhang, Xie, & Liu, 2023). When these elements are not properly regulated, they can lead to discomfort, discouraging people from using outdoor areas for recreation or other daily activities. Thus, controlling microclimatic conditions becomes a central aspect of urban landscape planning (Lin, Li, & Brown, 2022).

Vegetation especially trees has been proven to significantly influence microclimate regulation. Trees contribute to thermal comfort by providing shade that reduces surface and air temperatures (Sabrin, Karimi, Nazari, Pratt, & Bryk, 2021). Moreover, through the process of evapotranspiration, vegetation increases air moisture content, thereby impacting the relative humidity of an area (Zheng, et al., 2022). However, the effectiveness of vegetation in regulating climate is dependent on several factors, such as the density of the tree canopy, the spacing between trees, the type of ground cover beneath the vegetation, prevailing wind speeds, and sunlight intensity (cloudy versus sunny conditions) (Zhang, Lu, & Song, 2023). These variables must be carefully considered when designing vegetated spaces to ensure optimal environmental performance.

Understanding the specific role of vegetation in influencing outdoor thermal comfort is essential for landscape architects, urban designers, and environmental planners (Zou & Zhang, 2021). By studying the relationship between vegetation characteristics and climatic elements, professionals can make informed decisions that enhance the livability and sustainability of urban environments. Therefore, this study aims to examine the effectiveness of green belt vegetation particularly trees in reducing air pollution and regulating climate-related variables, specifically air temperature and relative humidity. Through this research, it is expected that a better understanding of vegetation's role in environmental comfort can be achieved, leading to more strategic green space planning in urban areas.

Vegetation plays a crucial role in regulating urban microclimates, particularly in modifying the distribution of air temperature and humidity. Numerous studies indicate that vegetation cover—such as trees, urban parks, and green infrastructure—can reduce air temperature through shading and evapotranspiration mechanisms, thereby significantly mitigating the *urban heat island* (UHI) effect. Areas with dense vegetation tend to exhibit lower temperatures compared to built-up areas lacking greenery; in tropical climates, temperature reductions can reach up to 12°C. Furthermore, vegetation functions as an ecological system that enhances environmental quality and thermal comfort through complex interactions among solar radiation, airflow, and atmospheric moisture (Wong et al., 2021; Gunawardena et al., 2021; Yuan et al., 2024).

However, the influence of vegetation on air humidity presents a more complex dynamic. The process of evapotranspiration not only reduces temperature but also increases relative humidity in the surrounding environment. Empirical studies reveal that areas with dense tree canopies tend to have cooler yet more humid air conditions compared to open spaces. This interaction between temperature and humidity directly affects thermal comfort indices such as the *Universal Thermal Climate Index* (UTCI), where increased humidity can limit the cooling benefits of vegetation to less than 3°C under certain conditions. In highly humid climates, elevated moisture levels may even reduce perceived thermal comfort despite lower air temperatures (Hwang et al., 2024).

Moreover, the relationship between vegetation cover, temperature, and humidity demonstrates significant spatial patterns influencing thermal comfort distribution. Research utilizing remote sensing techniques and NDVI (Normalized Difference Vegetation Index) analysis shows that higher vegetation density correlates with lower surface temperatures and improved thermal comfort levels. Vegetation also contributes to microclimate stability by reducing daily temperature fluctuations and enhancing overall urban environmental quality. Therefore, the integration of vegetation into urban planning should not be viewed merely as an aesthetic component, but rather as a critical climate adaptation strategy to improve thermal comfort and urban sustainability (Anindita et al., 2020; Gherri, 2023).

METHODOLOGY

This study was conducted at the Academic Event Plaza (AEP) of IPB University, Bogor. The field observation took place from 15:00 to 17:00 Western Indonesian Time (WIB). The location of the field practice is shown in Figure 1.

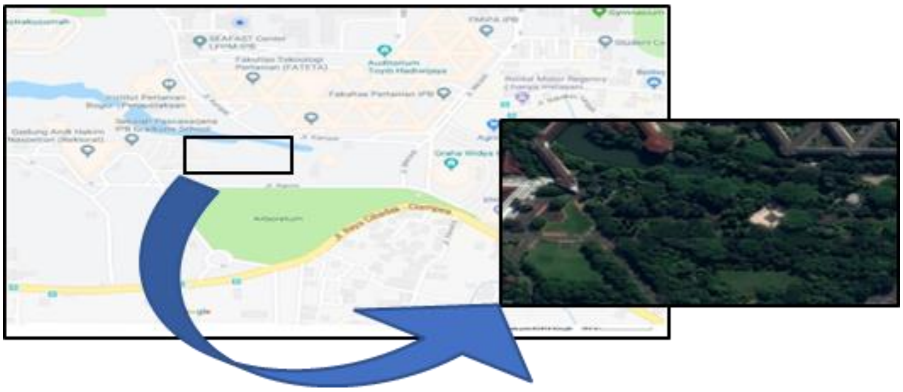

Figure 1. Academic Event Plaza

The tools and materials used in this study included an anemometer, thermohygrometer, weather station, tripod, writing tools, measuring tape, and bamboo stakes (Figure 2). These instruments were utilized to measure microclimatic parameters such as air temperature and relative humidity in the study area. The method employed in this practicum involved direct field observation following standardized procedures. The objective was to analyze the effect of vegetation particularly tree canopies on microclimatic comfort by comparing shaded and open areas as well as mapping the influence of vegetation cover on broader spatial temperature and humidity distributions.

The first part of the observation focused on measuring the effect of a single tree canopy on air temperature and relative humidity. A single tree whose canopy provided significant shade was selected, along with a nearby open area that served as the control. Air temperature and relative humidity were measured beneath the canopy and in the open area at 30-minute intervals for a duration of three hours, from 14:00 to 17:00. These data were then compared to determine the microclimatic differences between shaded and unshaded zones.

The second part of the observation aimed to assess the influence of vegetation cover on the spatial distribution of air temperature and relative humidity. A 40-meter by 60-meter plot was selected within the Academic Event Plaza. A grid system was established on the site with a spacing of 10 meters by 10 meters, and the corners of each grid were marked using bamboo stakes. Air temperature and relative humidity were measured at each grid point within a 30-minute time frame. Additionally, vegetation cover types including tree stands and ground cover were mapped within the grid. Based on the collected data, isotherm and isohygro maps were created with a contour interval of 0.5°C for temperature and 0.5% for humidity. These maps visually represented the spatial distribution of microclimatic variables and helped in understanding the moderating influence of vegetation on outdoor thermal comfort.

RESULTS AND DISCUSSION

The Effect of a Single Tree Canopy on Changes in Air Temperature and Humidity

Measurements of the effect of a single tree canopy on changes in air temperature and relative humidity were conducted in a designated area at the Academic Event Plaza (AEP). The measurements were taken beneath the canopy of a Couroupita guianensis tree, commonly known as the cannonball tree. This tree species has a dense, closed canopy structure, classified as a fully shaded crown. In addition to the shaded area, measurements were also taken in an open space that served as the control site. Air temperature and relative humidity were recorded using a weather station. Observations were carried out at 30-minute intervals. The measured differences in temperature and humidity between the shaded and open areas are presented in Table 1.

Table 1. The Effect of Couroupita guianensis Canopy on Air Temperature and Humidity Changes

No	Time (WIB)	Temperature (°C)		Humidity (%)	
		Under Canopy	Open Area	Under Canopy	Open Area
1	15 00	34,7	35,4	55	52
2	15.30	34,3	33,8	55	51
3	16.00	32,3	32,7	57	55
4	16.30	30,9	30,9	62	57
5	17.00	29,5	30,2	66	67

Table 1 shows a difference in air temperature between the area beneath the canopy of the cannonball tree and the open area, particularly noticeable during the first, third, fourth, and fifth 30-minute intervals. This indicates a consistent temperature difference between shaded areas under the tree canopy and unshaded, open areas. As shown in Figure 2, during the second 30-minute interval, the temperature in the open area was actually lower than in the shaded area, at 34.3 °C and 33.8 °C respectively. This anomaly occurred due to cloudy weather and light rain, which caused a rapid drop in air temperature in the open area as the heated air quickly dissipated and rose to a region of lower pressure. In contrast, the temperature beneath the tree canopy did not decrease as quickly, as the canopy trapped warm air underneath, making the shaded area relatively warmer during that time. The air temperature in both areas continued to decrease from the third to the fifth 30-minute intervals, influenced by persistent cloudy conditions, intermittent drizzle, and the decreasing intensity of solar radiation as the sun began to set in the west. The lowest recorded temperatures in each area were 29.5 °C (under the canopy) and 30.2 °C (in the open area). The temperature trends and differences between the shaded and open areas are illustrated in Figure 2.

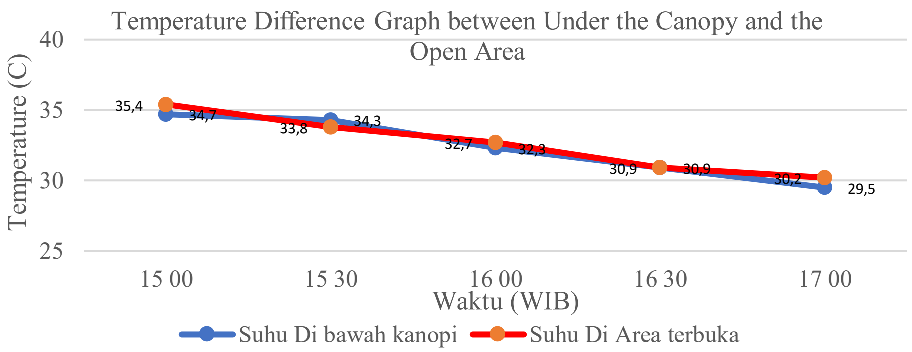

Figure 2. Temperature Difference Graph between the Tree Canopy Area and the Open Area

Table 1 also illustrates a difference in relative humidity between the area shaded by the cannonball tree canopy and the open area. From the first to the fifth 30-minute interval, there was a consistent difference in humidity levels, with the shaded area showing higher humidity percentages compared to the open area. As shown in Figure 2, the highest recorded humidity was at 17:00 WIB, reaching 66% in the shaded area and 67% in the open area. The drastic drop in humidity in the open area, compared to the shaded area, was due to the rapid release of warm air. In contrast, the shaded area retained more moisture as the air warmed under the canopy remained trapped. The increase in humidity levels was further influenced by cloudy skies, light drizzle, and the declining intensity of solar radiation as the sun began to set in the western horizon. The graph showing the trend in humidity percentage differences between the shaded and open areas is presented in Figure 3.

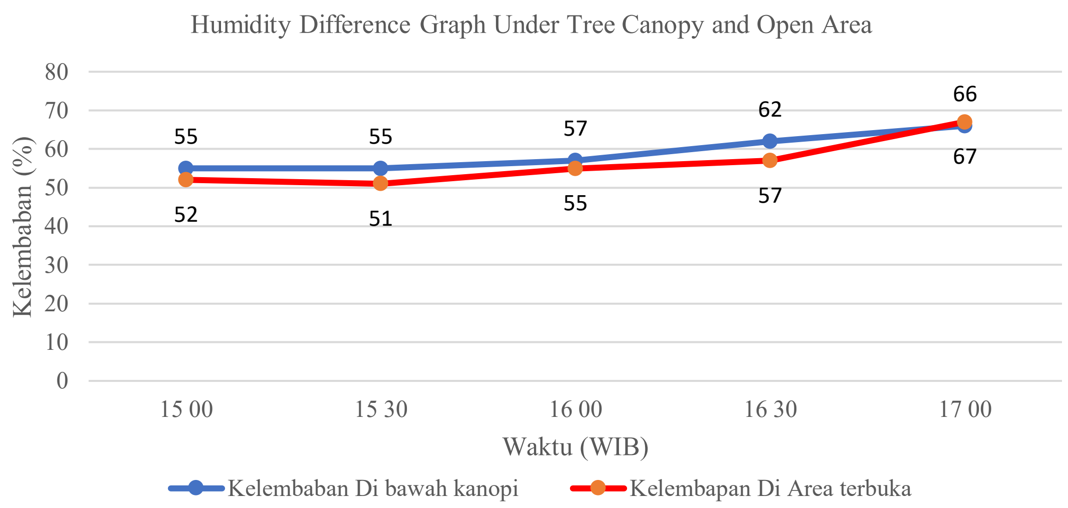

Figure 3. Humidity Difference Graph between the Tree Canopy Area and the Open Area

The Influence of Tree Canopy Coverage on the Distribution of Air Temperature and Humidity

Tree canopy coverage in a given area has a significant effect on the spatial distribution of air temperature and humidity. As previously observed in the comparison between a single tree canopy and an open area, differences in microclimatic conditions were evident. For this part of the study, the location remained the same Academic Event Plaza (AEP) with a measurement plot covering an area of 40 meters by 60 meters. The site was divided into 24 grid cells, each measuring 10 meters by 10 meters, as shown in Figure 4. A total of 35 measurement points for air temperature and relative humidity were recorded within a 30-minute period. The collected data, which include temperature, humidity, and the area covered by tree canopies, are presented in Table 2. To further analyze the effect of tree canopy coverage on the distribution of air temperature, a statistical approach using simple linear regression was employed. The results of this analysis are illustrated in Figures 5 and 6. In addition to tabular presentation, the spatial distribution of temperature and humidity was also visualized using isotherm and isohygro maps (Figures 7 and 8), which allow for easier interpretation of the spatial patterns of thermal and moisture conditions across the study area.

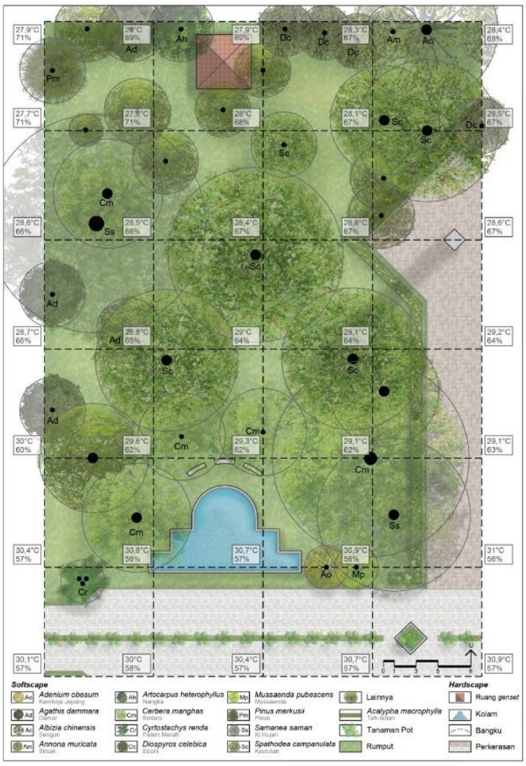

Figure 4. Site Grid, Canopy Cover Types, Temperature, and Humidity Values

Figure 4 illustrates the study site, which was divided into 24 grid cells. The image also shows the presence of more than 10 different tree species distributed across the site, each with varying canopy diameters. The total site area is 2,400 m², of which 1,555.1 m² is covered by tree canopies, 455.5 m² by paved surfaces and buildings, 322.2 m² by grass, and 55.1 m² by water bodies or ponds. Approximately 65% of the site is shaded by tree canopies, which significantly affects the distribution of temperature and humidity values within the site, contributing to the site's microclimate.

Table 2. Canopy Cover Area, Air Temperature, and Humidity Values

Measurement Point	Canopy Covered Area (m²)	Temperature (°C)	Humidity (%)
1	35,22	27,9	71
2	53,28	28,0	69
3	35,49	27,9	69
4	75,99	28,3	67

5	56,75	28,4	68
6	56,89	27,7	71
7	72,22	27,8	71
8	61,04	28,0	68
9	79,41	28,1	67
10	61,19	28,5	67
11	96,00	28,6	66
12	99,96	28,5	66
13	99,67	28,4	67
14	49,83	28,6	67
15	4,26	28,6	67
16	32,69	28,7	66
17	99,04	28,8	65
18	78,60	29,0	64
19	92,04	29,1	64
20	4,44	29.2	64
21	53,83	30,0	60
22	93,12	29,6	62
23	73,12	29,3	62
24	100,00	29,1	62
25	35,45	29,1	63
26	16,14	30,4	57
27	35,25	30,8	56
28	7,18	30,7	57
29	69,28	30,9	56
30	18,70	31,0	56
31	0,00	30,1	57
32	0,00	30,0	58
33	0,00	30,4	57
34	0,00	30,7	57
35	0,00	30,9	57

Table 2 presents the canopy cover area for each grid, along with temperature and humidity values recorded at 35 measurement points. The highest recorded temperature was 31 °C, while the highest recorded humidity was 71%. The table indicates a correlation and potential influence: in grids where the majority of the area is covered by tree canopies, lower temperature values and higher humidity levels are observed, and vice versa. To further examine the relationship and the influence of canopy cover on temperature reduction in a quantitative manner, regression graphs were generated. Figure 6 shows the regression of canopy cover area against temperature, while Figure 7 illustrates the regression of canopy cover area against humidity.

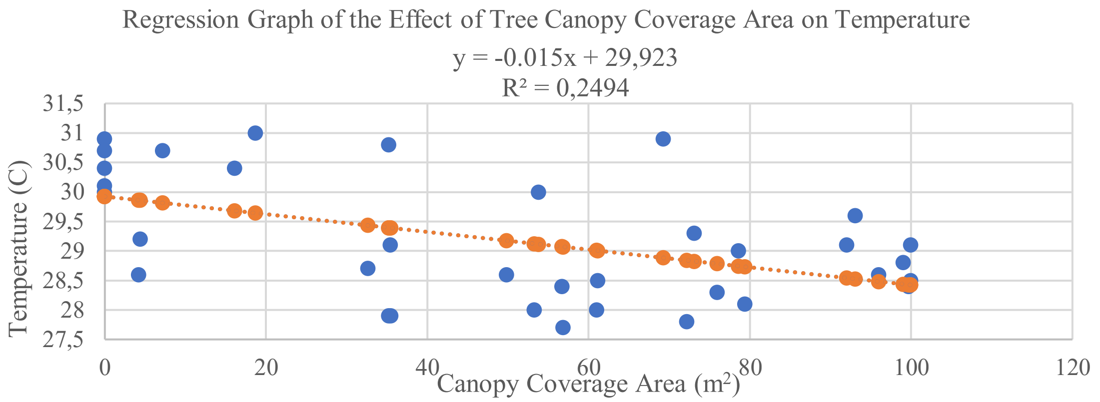

Figure 5. Regression Graph of the Influence of Tree Canopy Cover Area on Air Temperature

The regression equation representing the influence of tree canopy cover area on air temperature is expressed as Y = -0.015x + 29.923, with a coefficient of determination (R^2) of 0.2494. This equation indicates that for every one-unit increase in canopy cover area (x), the temperature (Y) decreases by 0.015 °C. The correlation value of 0.249 is categorized as moderate. It is important to note that correlation describes the strength of the relationship between two variables without implying causality that is, it does not determine which variable influences the other. In this context, both variables (canopy area and temperature) may interact, and the relationship may be influenced by external environmental factors such as wind speed and direction, as well as rainfall.

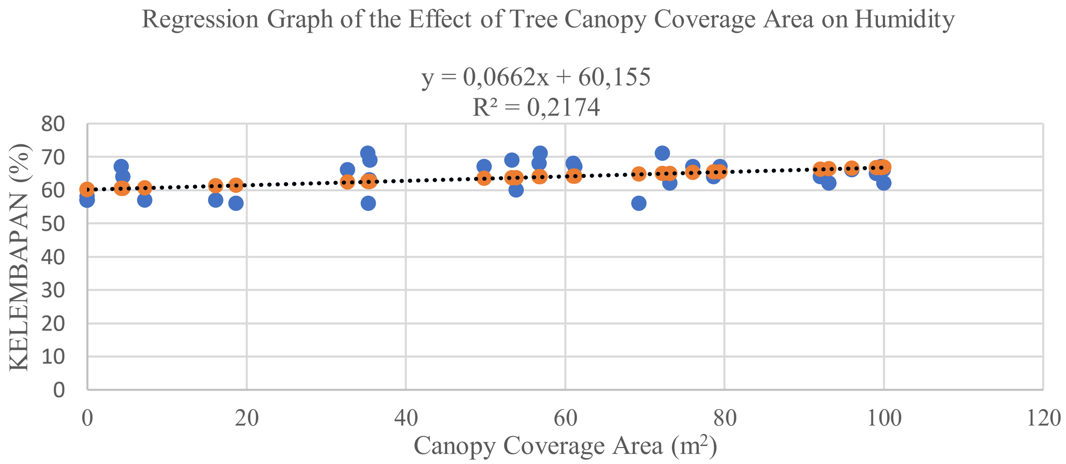

Figure 6. Regression Graph of the Influence of Tree Canopy Cover Area on Humidity

The regression equation representing the influence of tree canopy cover area on relative humidity is expressed as Y = 0.0662x + 60.155, with a coefficient of determination (R^2) of 0.2174. This equation indicates that for every one-unit increase in canopy cover area (x), the relative humidity (Y) increases by 0.0662%. The correlation value of 0.2174 is categorized as very weak. As with the previous regression, it is important to note that correlation describes the strength of the relationship but does not establish causation that is, it does not indicate which variable influences the other. Both variables, x (canopy cover) and y (humidity), may interact or be influenced by additional environmental factors such as wind speed and direction, or rainfall intensity. Furthermore, the spatial distribution of temperature and humidity across the site was visualized through isotherm and isohygro maps. These maps display areas with equal temperature and humidity values, respectively, making it easier to observe microclimatic patterns across the site. The isotherm and isohygro maps are presented in Figures 7 and 8, respectively.

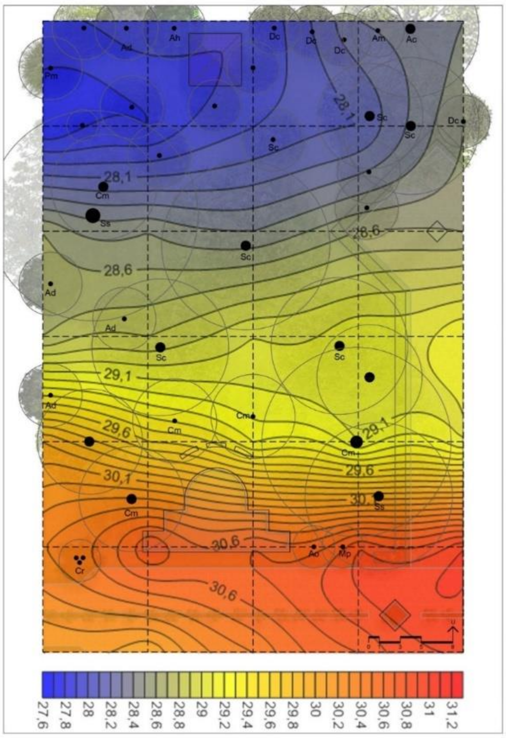

Figure 7. Isotherm Map of the Study Site

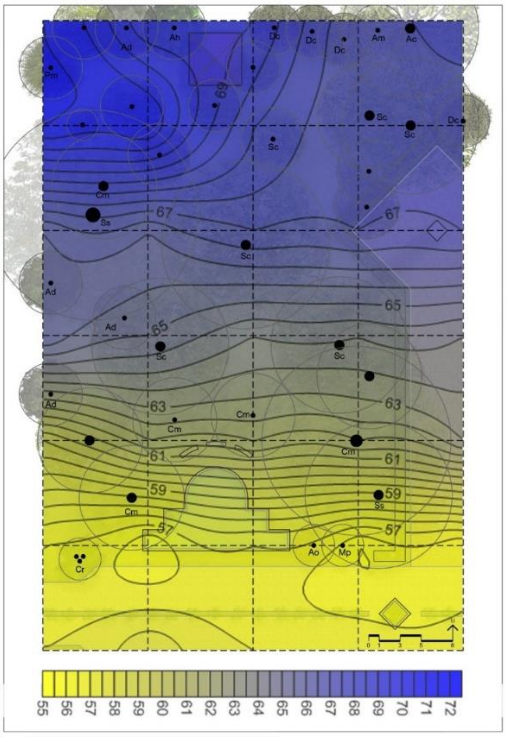

Figure 8. Isohygro Map of the Study Site

As shown in Figure 7, the northern part of the site is shaded in blue to yellow, indicating that the temperature in this area is lower compared to other regions. This is further supported by the isotherm lines, which fall within the range of 28.1 °C to 29.1 °C. Moving southward, the color gradient shifts to orange and red, signifying higher temperatures in that part of the site. The isotherm lines in the southern region correspond to temperatures between 29.6 °C and 30.6 °C. The map also shows that the areas shaded in blue to yellow are predominantly covered by tree canopies, which contribute to the lower temperatures in those zones. In contrast, the orange and red areas represent regions with sparse or no canopy cover, resulting in higher surface temperatures compared to other parts of the site.

As illustrated in Figure 8, the northern part of the site is shaded in blue to bluish-gray, indicating higher humidity levels in this area compared to other regions. This is supported by the isohygro lines, which fall within the range of 65% to 69%. Moving southward, the color shifts to grayish-yellow and then to yellow, representing areas with lower humidity levels. The isohygro lines in this southern region correspond to 63% to 57% humidity. The map also reveals that areas shaded in blue to bluish-gray are largely covered by tree canopies, contributing to higher humidity levels. Conversely, the grayish-yellow to yellow regions represent areas with sparse or no canopy cover, resulting in lower humidity levels compared to the rest of the site.

CONCLUSIONS AND RECOMMENDATIONS

Temperature and humidity (temperature reduction and humidity increase) within a site. These two climatic elements play a significant role in creating a comfortable environment, highlighting the importance of microclimate amelioration through the integration of vegetation particularly tree canopies into landscape design. The selection of vegetation should also consider crown shape and foliage density in order to enhance thermal comfort. Furthermore, it is essential to account for other elements that may act as external factors (Z factors) influencing the microclimatic conditions of a given site or landscape.

ADVENCED RESEARCH

This research still has limitations, so further research is needed related to the topic of The Influence of Vegetation Cover on Temperature and Humidity Distribution Affecting Thermal Comfort in order to perfect this research and increase insight for readers. Future research should examine the influence of vegetation characteristics such as canopy shape, leaf density, and tree species on thermal comfort using more comprehensive parameters, including PET and UTCI. In addition, the use of GIS technology, remote sensing, and digital microclimate simulation can provide more accurate spatial analyses of temperature and humidity distribution in tropical urban areas.

Further studies are also recommended to explore the relationship between microclimate conditions and user behavior and perception in green open spaces. Research integrating thermal comfort, social activities, and environmental quality will provide a more holistic approach to landscape planning and sustainable urban development.

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