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QUANTIFYING THE COOLING EFFECT FOR URBAN PARK MICROCLIMATE: AN ANALYSIS OF *PELTOPHORUM PTEROCARPUM* SPECIES IN KLCC PARK, KUALA LUMPUR, MALAYSIA

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Abstract

Many cities worldwide are concerned with the urban heat island (UHI) effect. Rising temperatures negatively impact urban microclimates. However, vegetation can help to mitigate this effect. A particular tree species, Peltophorum pterocarpum (Yellow Flame) is the subject of this study's preliminary inquiry into its cooling effects. This study used a particular technique and statistical analysis to examine the unique cooling ability of Peltophorum pterocarpum in the urban park setting. This study will estimate the Peltophorum pterocarpum species' overall cooling effect by considering density and surface. It has led to a correlation coefficient of [0.75], signifying the magnitude and direction of the association between Peltophorum pterocarpum density and surface temperature. The species exhibits provided substantial shade coverage and resulting in a notable reduction in temperature. The outcomes of this research are expected to provide valuable insights for urban microclimate management, particularly in the context of parks and similar environments. By quantifying the cooling effect of Peltophorum pterocarpum, this study contributed evidence-based guidelines for urban planners and landscape designers, facilitating informed decision-making regarding vegetation selection and integration. Implementing these findings can effectively alleviate the urban heat island (UHI) effect, enhancing the liveability and sustainability of urban areas.

Keywords: Cooling, Urban Park microclimate, Urban Heat Island (UHI), *Peltophorum pterocarpum*

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INTRODUCTION

The urban heat island effect, characterized by elevated temperatures are more prominent in urban areas compared to surrounding rural regions and has become a growing concern in cities worldwide. Resulting in adverse impacts on human health, energy consumption, and overall urban comfort have propelled the exploration of strategies to mitigate this effect. Among these strategies, the cooling effect of vegetation has emerged as a promising solution, offering multiple benefits for urban microclimates. KLCC Park, situated in the heart of Kuala Lumpur, Malaysia, is a renowned urban green space known for its aesthetic beauty and recreational value. However, the specific contributions of vegetation, particularly tree species, in reducing this park's urban heat island (UHI) effect still need to be explored. Hence, this research aims to quantify the cooling impact of vegetation on the urban microclimate of KLCC Park, with a specific focus on analysing the *Peltophorum pterocarpum* species. *Peltophorum pterocarpum* was chosen because of its prominence in KLCC Park and its potential as a significant contributor for temperature reduction. Thus, this study focuses into the cooling capabilities of *Peltophorum pterocarpum*, thoroughly examining surface temperatures in both paved and turfed areas beneath its canopy. This investigation also considers factors such as tree density and surface coverage to gauge the efficacy of *Peltophorum pterocarpum* in reducing the urban heat island effect within the area of KLCC Park. This study involved a quantitative assessment of its cooling influence. The study will provide insights into the tree species' effectiveness in alleviating the urban heat island effect and enhancing the microclimate conditions within KLCC Park. Understanding the cooling effect of *Peltophorum pterocarpum* and its specific contributions to the urban microclimate of KLCC Park holds substantial practical implications. It can provide evidence-based guidance for urban planners and landscape architects in optimizing the selection and placement of tree species within the park to enhance its cooling potential. Additionally, the findings from this research can contribute to a broader urban microclimate management strategy, aiding in the development of sustainable and climate-resilient cities. A thorough literature analysis will synthesize existing knowledge on the cooling effect of vegetation on urban microclimates, the particular significance of tree species, and the methodology used to quantify this effect to meet study objectives. This research will involve field measures, including surface temperature monitoring, to determine the cooling effect of *Peltophorum pterocarpum* trees for KLCC Park. Through this study, it will be possible to understand how *Peltophorum pterocarpum* cooling capacity and its effect on the urban microclimate of KLCC Park. Ultimately, the findings will add to the knowledge of managing urban microclimates and offer helpful information for sustainable urban planning and design.

Urban Microclimate and Urban Heat Island (UHI)

Urban microclimate refers to the localized climatic conditions within urban areas that differ from the surrounding rural environment (Priya, U. K and Senthil, R., 2021; Wong, N. H., et al. 2021). It resulted from various interactions between urban structures, land use, and atmospheric processes. Urban microclimates often exhibit distinct characteristics, including elevated temperatures, altered wind patterns, and modified humidity levels (Abdullah, S., et al. 2021). The Urban Heat Island (UHI) phenomenon arises from sunlight that the earth's surface cannot absorb due to urban areas comprising skyscrapers, concrete structures, and paved roads (Yang, L., et al. 2016). The previous study done by Kim, S. W., and Brown, R. D. (2021) mentioned that lack of space for heat absorption by the earth's surface results in elevated temperatures during both day and night, causing the released thermal heat to intensify in urban areas during the night. In Kuala Lumpur, the city centre registers a temperature of 32°C, while the outskirts in Titiwangsa report 26°C (Isa, N. A., Wan Mohd, W. M. N., and Salleh, S. A., 2017). This clearly signals the presence of the Urban Heat Island effect within urban areas. This phenomenon is attributed to various factors, including the prevalence of glass-covered building structures incapable of absorbing the existing heat. For instance, the KLCC Tower, constructed with glass facades, substantially exacerbates most of the UHI effect in Kuala Lumpur (Elsayed I.S, 2012a; Malaysian Meteorological Department, 2023). According to Elsayed I.S., (2012a, 2012b), the diminishing presence of greenery in Kuala Lumpur's urban areas impedes the city's heat absorption process, primarily due to the scarcity of vegetation and shade. Green plants and trees are vital in urban environments as they indirectly contribute to lowering local temperatures from 21°C to 18°C, thereby mitigating the UHI effect (Elsayed I. S., 2006.; Mitchell, 1953, 1961). Efforts to mitigate UHI effects involve various strategies, including promoting green infrastructure, implementing cool roofing and pavement technologies, and urban planning policies that encourage sustainable development practices (Brown, Robert., 2011: Soydan, O., 2020). Vegetation, including trees and green spaces, is vital in mitigating UHI by providing shade, evaporative cooling, and reducing heat absorption. By understanding the dynamics of urban microclimate and UHI is crucial for developing effective strategies to combat the adverse impacts of excessive urban warming. This knowledge formed the backdrop for the investigation into the cooling effects of *Peltophorum pterocarpum* in KLCC Park, Kuala Lumpur.

The Role of Vegetation in Cooling Effect

Vegetation, including trees, shrubs, and green spaces, served as a natural climate regulator in urban environments. These green elements play a crucial role in mitigating the adverse effects of urbanization, particularly the UHI effect. Their contributions to urban cooling can be attributed to several key mechanisms: (i) shade and temperature reduction- one of the most apparent cooling effects of vegetation is the provision of shade (Elsayed, I. S., 2012b; Lindberg, F., & Grimmond, C. S. B., 2011; Akbari, H., Pomerantz, M., & Taha, H. 2001). Previous study by Akbari H., et al. (1992) and Shahidan, Mohd. F., et al. (2010) stated the trees and canopy cover create sheltered areas that reduce direct exposure to solar radiation, leading to cooler surface temperatures. In densely populated urban areas, these shades can significantly lower ambient temperatures during hot summer months, making outdoor spaces more comfortable for residents, (ii) transpiration and evaporative cooling- vegetation, through a process called transpiration, releases water vapor into the atmosphere (Morabito, M, et al. 2021; Jiao, M, et al. 2021). This evapotranspiration process cooled the surrounding air and surfaces. As plants draw water from the soil and release it into the atmosphere, they effectively dissipate heat and reduce the local temperature. This cooling effect is particularly noticeable during periods of high temperatures and can counteract the heat generated by urban activities (Yao, L., Sun, S., Song, C., Wang, Y. and Xu, Y., 2022) and (iii) urban planning and green infrastructure- Urban planners and policymakers increasingly recognize the importance of green infrastructure, such as urban parks, green roofs, and street trees, in urban cooling strategies (Lindberg, F., & Grimmond, C. S. B., 2011). Integrating vegetation into urban planning and design can help to create a more sustainable and liveable cities while addressing the challenges posed by urban warming. Understanding the multifaceted role of vegetation in urban cooling is essential for developing effective strategies to combat the UHI effect and enhance the quality of urban environments. This knowledge focuses on the significance of analysing the cooling effects of *Peltophorum pterocarpum* in KLCC Park, Kuala Lumpur, as it contributed to the broader understanding of urban green infrastructure's impact on microclimates and human comfort.

***Peltophorum pterocarpum*: Specific Cooling Effect**

Peltophorum pterocarpum, commonly known as Yellow Flame tree, is a tropical tree species native to regions in Southeast Asia, including countries like India, Sri Lanka, Malaysia, and Indonesia. While it is primarily valued for its ornamental qualities, this tree species also has some specific cooling effects, which can be beneficial for the environment and urban areas. Details about the specific cooling effect of *Peltophorum pterocarpum*: (i) shade production- the tree's broad canopy and dense foliage create a substantial area of shade underneath it. This shade helps in reducing the temperature of the surrounding environment by blocking direct sunlight and preventing solar radiation from heating the ground (ii) temperature reduction- the shade cast by the Yellow Flame tree can lead to a significant reduction in ambient temperature. According to a study done by Edward F. and Dennis G. (2011), in urban areas, where heat-absorbing surfaces like concrete and asphalt do contribute to higher temperatures (UHI effect), the presence of these trees can counteract the heat buildup and create microclimates with lower temperatures, (iii) cooling of surfaces. Based on previous study done by Li, Y. C., et al. (2019), stated that the shade provided by the Yellow Flame tree extends not only to the air but also to the surfaces beneath it. This includes the ground and any nearby buildings or structures. By preventing these surfaces from absorbing excessive heat, the trees helped maintain lower temperatures in its immediate surroundings, and (v) urban heat island mitigation- In urban planning, *Peltophorum pterocarpum* trees are often used as part of strategies to mitigate the urban heat island effect (Jain, B., Pancholi and Jain, R., 2011). Introducing greenery and shade in urban environments they help reduce the overall temperature differential between urban and rural areas. In summary, the cooling effect of *Peltophorum pterocarpum* is primarily due to its shade production, transpiration, and ability to reduce surface temperatures. These specific cooling mechanisms make it a valuable addition to urban landscapes, contributing to local temperature reduction and enhancing the overall comfort of outdoor spaces.

Figure 1: Sample chosen for field measurement: *Peltophorum pterocarpum*
Source: Author, 2022

DESIGN & METHODS

This research utilizes an exploratory methodology to gather data through observation and case studies. The selection of *Peltophorum pterocarpum* was noted within two specific areas, turfing and pavement, covering 100 square meters (10 meters x 10 meters). Quantitative data was collected at various times over three days to assess surface temperature variations visually.

Context of the Study

This research has selected KLCC Park as its focal site for the following reasons it's central location and urban green space- nestled in the core of Kuala Lumpur. KLCC Park is an ideal hub for executing various fieldwork methodologies, conducting surveys, making observations, and collating essential data. The study of KLCC Park presents an opportunity to delve into the crucial role of urban green spaces within a bustling cityscape. This exploration encompasses the impact of such spaces on the urban populace's well-being, their roles in biodiversity preservation, fostering environmental sustainability, and promoting community engagement.

Data Measurement: Environmental Climate Data

This study's focus is solely on environmental climate data, namely one (1) variable out of five (5) variables that influence the microclimate in urban open spaces, which is surface temperature. Variables concerning canopy transparency rate (Daylight luminance), such as the flow of absorbed heat (thermal) by tree canopies, humidity, air temperature and wind speed, are not included in this study as they have minimal impact on the ambient temperature in the surrounding areas (Sharmin, M., et al. 2023; Liu, H., et al. 2023). The primary goal of the study is to concentrate more on the microclimate factors (surface temperature) to quantifying the cooling effect in grassy and turfed areas beneath the canopy. The categories of data to be collected are surface temperatures for two (2) study spots. The environmental climate data collection procedure was done for eight (8) hours, from 9:00 am until 5:30 pm, with a 30-minute interval for each study spot. Each day represented eighteen (18) data readings taken for the two (2) study areas. The selection of months for fieldwork was based on the analysis of Kuala Lumpur's Annual Climate Data. This study area was systematically observed separately for a total of 3 days: in May 2023 (1 day), July 2023 (1 day), and September 2023 (1 day). According to the data by Malaysian Meteorological Department (MET Malaysia, 2023), climate change make July the hottest month in 2023. Consequently, 54 sets (18 readings per day x 3 days) of data were collected for the measured study parameters in each study spot. The selection of study spots with *Peltophorum pterocarpum* trees covered an area of 100 square meters (10 meters x 10 meters). Spot 1 and Spot 2 were densely planted vegetation comprised of eight (8) tree stems within an area of 100m², with canopies exceeding 4.5 meters. All gathered data will subsequently undergo analysis. Relationships between each microclimate factor (surface temperature) of the *Peltophorum pterocarpum* trees at each study spot were tabulated into charts and graphs using Microsoft Excel and statistically analysed using the Statistical Package for the Social Sciences (SPSS) software. This study used appropriate tools (instruments) to facilitate data collection at the study site, ensuring efficient and accurate results. Some of the supportive tools used include: (i) FLUKE Thermal Imager to measure surface temperatures (°C) and captured temperature images for specific areas. This tool can display thermal profiles and the recorded surface temperatures and (ii) OAKLON TemTestr to measure surface temperatures (°C), and it allowed for close measurement of any object. The procedure for measuring the surface temperature measurements within the tree canopies were taken using the OAKLON TemTestr. This device was positioned beneath the tree canopy on the pavement and turf surfaces. The device was placed 1 meter below the canopy and 1 meter away from the designated research surface area.

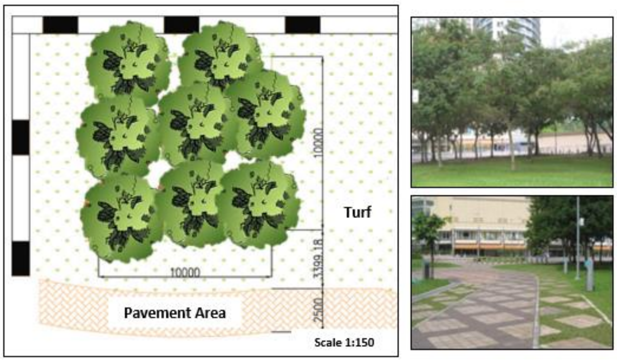


Figure 2: Spot (1) refers to dense vegetation beneath the grassy canopy surface
Source: Author, 2023

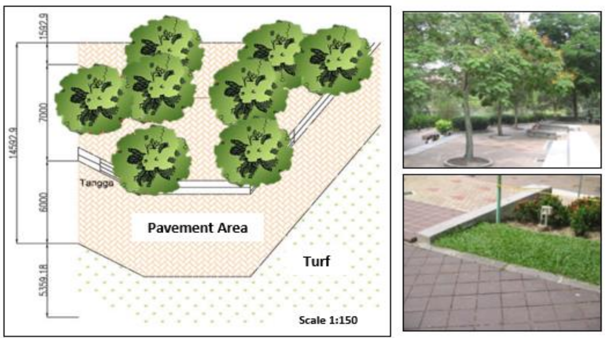
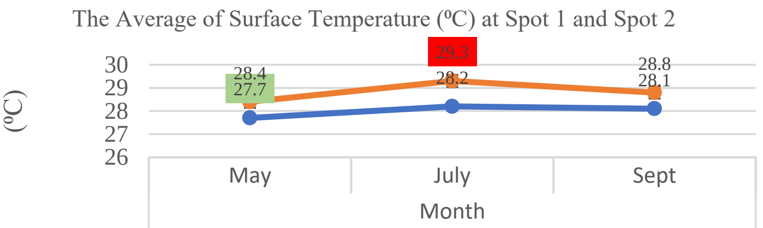


Figure 3: Spot (2) refers to dense vegetation beneath the pavement canopy surface
Source: Author, 2023

FINDINGS & ANALYSIS

The findings summarized that surface temperature data collected from Spot (1) with a turf canopy and Spot (2) with a pavement canopy over three days (March, May, and July 2023). The results revealed distinct temperature trends between the two sites. Specifically, Spot (1) within the turf canopy exhibited the lowest temperatures at 9:00am, 9:30am, and 2:00pm. In contrast, Spot (2) in the pavement canopy depicted the highest temperatures between 2:30pm and 3:30pm. The lowest surface temperature of 25.0°C and 25.5°C was recorded between 9:00 and 9:30 in the morning in both the turf canopy area (Spot 1) and the pavement canopy area (Spot 2). The peak surface temperature reached at Spot 1 occurred at 2:00 - 2:30pm, measuring 30.5°C. Meanwhile, the highest temperature of 32.5°C was recorded at 2:30 in the afternoon in the pavement canopy area (Spot 2). Spot 1 exhibit surface temperature fluctuations throughout the day, reaching its peak around 2:00 - 2:30pm. Conversely, Spot 2 generally maintains slightly higher temperatures and reached its peak around 3:00 - 3:30pm. There was an increase of temperature at the pavement canopy area (Spot 2) of average 32.3°C at 2:30 in the afternoon, rising from 28.5°C to 33.0°C. In contrast, in the turf canopy area (Spot 1), the surface temperature with an average of 28.2°C from May, July and September 2023 at 2:30 in the afternoon. Throughout the three-day observation and surface temperature measurements, the average surface temperature analysis between 9:00 in the morning and at 5:30 in the evening at the turf canopy area (Spot 1) was lower, at 27.0°C, compared to the surface temperature at the pavement canopy area (Spot 2) at 30.0°C, showing a difference of 3.0°C. Across all time intervals, Spot 2 consistently exhibit slightly higher average surface temperatures in comparison to Spot 1. Moreover, while both locations displayed temperature fluctuations, Spot 2 notably registered higher temperatures, particularly during the midday period. The surface temperature analysis for Spot 1 revealed a gradual rise in temperatures from May, recorded at 27.7°C, to July, showing a slight increase to 28.2°C, followed by a relatively stable surface temperature in September, recorded at 28.1°C. Conversely, Spot 2 exhibited a distinct surface temperature pattern, displaying a substantial increase in temperatures from May, marked at 28.4°C, to July, recording a peak of 29.3°C, before experiencing a slight decline in September to 28.8°C. Based on Figure 4, the average temperature recorded for Spot 1 across all time intervals was 27.7°C, while for Spot 2, it was slightly higher at 28.4°C.



	May	July	Sept
SPOT 1	27.7	28.2	28.1
SPOT 2	28.4	29.3	28.8

Figure 4: The Average of Surface Temperature (ºC) at Spot 1 and Spot 2
Source: Author, 2023

These observations underlined varying surface temperature fluctuations across the months for both Spot 1 and Spot 2, showcasing distinct changes in surface temperature trends between the different periods and different covered or shaded. When compared, the surface temperature variances between Spot 1 and Spot 2 across different months revealed consistent differences. In May, Spot 2 displayed temperatures approximately 2.54% higher than Spot 1, recording 28.4°C compared to Spot 1's 27.7°C. This trend continued up until July, where Spot 2 registered surface temperatures approximately 3.90% higher than Spot 1, with readings of 29.3°C and 28.2°C, respectively. Similarly, in September, Spot 2 maintained temperature around 2.50% higher than Spot 1, recording 28.8°C compared to Spot 1's 28.1°C. These percentage differences consistently indicated higher surface temperatures in Spot 2 compared to Spot 1 across the observed months. Across all analyses, Spot 2 consistently demonstrated higher surface temperatures than Spot 1, exhibiting noticeable fluctuations in May, July, and September. Notably, July is the warmest month for both Spot 1 and Spot 2. The result of the correlation coefficient between a *Peltophorum pterocarpum* density (X) of 8 and surface temperatures (Y) of 27.7°C, 28.2°C, and 28.1°C was calculated to determine their relationship, resulting in a correlation coefficient of [0.75], indicating the strength and direction of the relationship between *Peltophorum pterocarpum* density and surface temperature. This suggested that higher tree density at this fixed value correlates significantly with higher surface temperatures within the dataset, implying a consistent association between the two variables.

DISCUSSION

After assessing the influence of *Peltophorum pterocarpum* species on the urban microclimate of KLCC Park. The data collected unveiled a compelling association between these plants and temperature regulation, emphasized their potential significance in combating urban heat island effects. Based on the analysis and findings, the results indicated that:

a) Difference of surface between Spot 1 and Spot 2: Consistently across the recorded months, Spot 2, designated as the pavement area, consistently demonstrated slightly elevated temperatures compared to Spot 1, which represented the turf area. The nature of the turf area (Spot 1) and pavement area (Spot 2) likely contributed to the observed temperature differences, with pavement surfaces typically absorbing more heat than turf surfaces. This finding showed that it can be attributed to the inherent properties of these surfaces. Pavement surfaces have a higher capacity to absorb and retain heat when compared to turf surfaces due to their composition and thermal properties. The previous study conducted by Shamsaei, M.; Carter, A.; Vaillancourt, M. A (2022), highlighted that pavement, being darker and having lower albedo, tend to absorb more solar radiation and heat, leading to higher surface temperatures in urban areas. In addition, research by Hachem et al. (2016) in the journal Landscape and Urban Planning also discusses how surface materials, particularly pavements with higher thermal conductivity, contributed significantly to increased urban heat island effects due to their heat-absorbing nature.

b) Tree density: The consistent *Peltophorum pterocarpum* tree density set at 8 displayed a noticeable trend where surface temperatures tend to consistently rise. This observation underlined the significant influence of constant tree density on surface temperatures, primarily attributed to shading effects and enhanced evapotranspiration. A previous study done by Dina and Lin (2023) stated the vegetation successfully lowered air temperature (Ta) and minimized exposure to solar radiation on pavement concrete, thereby alleviating outdoor heat stress. Hence, maintaining a specific tree density can impact surface temperatures by reducing direct exposure to sunlight through increased shading. This shading mechanism mitigates the absorption of solar radiation, subsequently contributing to lower surface temperatures within shaded areas. Sharmin, M., Tjoelker and M.G., Pfautsch, S. (2023), highlighted the role of increasing tree density in urban spaces, emphasizing how trees' shading properties effectively reduce direct solar radiation, consequently lowering surface temperatures. Additionally, Abdi, B., Hami, A., Zarehaghi, D. (2020) and Streiling, S. (2003) accentuate the impact of higher tree density on surface temperature reduction, interpreted how increased shading and enhanced evapotranspiration processes led to greater cooling effects. These studies collectively support the notion that maintaining higher tree density can effectively contribute to cooler surface temperatures by leveraging shading effects and intensified moisture loss through transpiration and evaporation, thereby shaping a more favourable microclimate.

CONCLUSION

To comprehensively address the challenges posed by urban heat islands, it becomes evident that specific recommendations for further study are necessary. While the selected variables, surface temperature, aligns with the primary goal of quantifying the cooling effect in grassy and turfed areas beneath the canopy, excluding other pertinent variables restricts the study's overall comprehensiveness. Future research endeavours should adopt a more inclusive approach, delving into additional microclimate factors to offer a more holistic understanding of cooling dynamics in urban open spaces. The initial focus should concentrate on detailed research into the nuanced impacts of diverse tree species on microclimate regulation, identifying those that excel in optimal shading and evapotranspiration. Simultaneously, the importance of sustained, long-term monitoring becomes apparent, evaluating how changes in tree density and surface materials affect microclimates across varying seasons. Integrating tree planting and surface material selection into urban planning strategies is important for establishing more resilient and thermally comfortable urban environments. Concurrently, efforts should be directed towards exploring methods to engage communities in tree-planting initiatives and elevate awareness about the heat mitigation benefits of vegetation. In conclusion, sustained investigation into specific tree species, ongoing monitoring, innovative urban planning, and proactive community involvement hold significant promise in developing effective strategies to counteract the urban heat island effects and foster sustainable, habitable urban spaces.

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