ROADSIDE GREENBELT EFFECTS ON THERMAL COMFORT OF PEDESTRIAN CORRIDORS AT A BUSY TRAFFIC ROAD

Article *in* Journal of Environmental Science and Sustainable Development · July 2024

DOI: 10.7454/jessd.v6i2.1201

4 authors:

Nur Intan Simangunsong
Universitas Trisakti

Reza Fauzi
Universitas Trisakti

Dibyanti Danniswari
Universitas Trisakti

Rini Fitri
Universitas Trisakti

Journal of Environmental Science and Sustainable Development
Volume 6, Issue 2, Page 249-265
ISSN: 2655-6847
Homepage: http://scholarhub.ui.ac.id/jessd

ROADSIDE GREENBELT EFFECTS ON THERMAL COMFORT OF PEDESTRIAN CORRIDORS AT A BUSY TRAFFIC ROAD

Nur Intan Simangunsong[1*], Reza Fauzi[1], Dibyanti Danniswari[1], Rini Fitri[1]
[1]Landscape Architecture Study Program, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, 11440, Indonesia

[*]Corresponding author: nurintan@trisakti.ac.id

(Received: 5 May 2023; Accepted: 5 December 2023; Published: 31 December 2023)

Abstract

The increasing number of motorized vehicles in Jakarta is causing environmental damage and can harm human health. In recent years, the Jakarta local government has the vision to focus on improving the human mobility network, including the pedestrian networks. As a heavily trafficked road, Jalan Kyai Tapa, West Jakarta, is used by many people. However, it may feel uncomfortable to walk there due to heat and sun exposure, which is compounded by extensive pavement coverage. The thermal condition of the pedestrian corridor is essential to create a comfortable walking experience. The objective of this study was to analyze the thermal comfort of the pedestrian corridors at Jalan Kyai Tapa concerning the landscape composition, including vegetation structure and pavement. This study was conducted quantitatively. This study identified the vegetation structure, including the tree species, canopy diameter, and height. Then, we measured the air temperature and relative humidity at predetermined measurement points to evaluate thermal comfort using the Temperature Humidity Index (THI). The results showed that the air temperature ranges from 31.01°C to 31.54°C, and the relative humidity ranges from 56.19% to 57.74%. The average THI value is 28.52 °C, which falls into the comfortable category. Despite having relatively wide canopies and providing shade, the trees in this pedestrian corridor do not seem to improve the thermal environment enough to achieve comfortable conditions for pedestrians. Interestingly, the result shows that, at certain observation times, points without trees had lower air temperatures compared to other spots with trees. Trees may not be the most influential factor in improving pedestrian thermal comfort. Furthermore, the spots near trees with more expansive canopies can be less comfortable than spots near trees with smaller canopies. Tree species and the planting spacing determine the efficiency of trees to improve thermal comfort.

Keywords: Koridor; Pedestrian way; Thermal comfort; Vegetation.

1. Introduction

The urban population has kept increasing in the past few decades. The population growth in Jakarta from 2010-2020 is about 0.92% (Badan Pusat Statistik (BPS), 2021). The population increase follows the increase in motor vehicles. In 2019, the motor vehicle increase in Jakarta was 0.7% compared to the previous year. Jakarta, infamous for its severe traffic congestion due to overloaded motor vehicles, would suffer more. Increasing the number of motor vehicles means more emissions of air pollutants and greenhouse gases that could eventually harm human health and the environment. If the environment is damaged, pedestrians are the most impacted group of road users, as they are directly exposed to the environment. Adding and preserving roadside greenbelts in the city is a way to alleviate the negative impact of motor vehicles on users and the environment.

A roadside greenbelt is a linear green open space formed by landscape elements, such as trees and shrubs, providing users comfort, safety, and beauty (Departemen Pekerjaan Umum, 1996). Existing studies found that trees in urban areas play a role in microclimate amelioration, air quality improvement, carbon dioxide reduction, oxygen production, ecological function, and city's water supply protection (Nowak et al., 2006; Biao et al., 2010; Simangunsong et al., 2021; Simangunsong & Fitri, 2021). Greenbelt trees and other forms of urban greenery provide ecological function and ecosystem services (Childers et al., 2019).

In urban climate, vegetation at roadside greenbelts is an important design element to ameliorate microclimate and to improve outdoor thermal comfort (Picot, 2004; Spagenberg, 2004). Roadside greenbelts offer various benefits to improve urban environment quality (Samsoedin & Waryono, 2010), such as ameliorating microclimate, reducing pollutants, including particle and gas, controlling glare, producing oxygen (Simangunsong et al., 2021; Simangunsong & Fitri, 2021), reducing noise, controlling wastewater, controlling soil erosion, reducing stress, preserving biodiversity, providing wildlife habitat, prevention of seawater intrusion, improving urban aesthetic values, and supplier of groundwater. The vegetation type and species must be carefully selected by considering its natural habitat, bioclimatic factors, ecological functions, and architectural functions to optimize the role of roadside vegetation. Additionally, selecting the local species would make the adaptation more accessible for the vegetation (Oduor et al., 2016). Vegetation at roadside greenbelts can improve the thermal environment, not only on a micro scale but also at a city scale.

Roadside greenbelts offer many benefits to the environment that indirectly benefit humans as well. The direct benefits of roadside greenbelts to humans are providing shade, user safety, and improving users' comfort, especially pedestrians and cyclists. The position of the greenbelt influences the wind effect for pedestrians (Zeng et al., 2022). Wind could be dangerous for users if it is too strong, but mild wind could improve users' thermal comfort, especially in hot weather. Thermal comfort is the term used to describe satisfaction with the thermal environment. Outdoor thermal comfort is influenced by the building–environment interaction, which includes various factors such as height of buildings, relative humidity, air temperature, sky view factor, wind speed, and street width (Achour-Younsi & Kharrat, 2016). Air temperature and relative humidity directly influence THI, an index used to measure human body comfort. By paying attention to the thermal comfort of roadside greenbelts, we can improve the walkability of urban pedestrian corridors.

Other than thermal comfort, the comfortability of pedestrian corridors is influenced by circulation, accessibility, safety, cleanliness, and aesthetics. Vegetation in roadside landscape serves as a view controller, physical barrier (Cabral et al., 2023), microclimate regulator (Cai et al., 2022), air pollution mitigator (Baldauf, 2020), wildlife habitat (Fischer et al., 2022), and aesthetic function (Qin et al., 2023). To create a sustainable roadside landscape, we must carefully select the vegetation species, the amount, and the planting design and manage the landscape. A pedestrian corridor is formed by softscape (vegetation) and hardscape (pavement, shelter, etcetera). The interaction between softscape and hardscape determines thermal comfort.

Jakarta's local government initiated the concept of a Smart City in 2014 by improving the city based on six elements: Smart Economy, Smart Governance, Smart People, Smart Mobility, Smart Environment, and Smart Living (Syalianda & Kusumastuti, 2021). This concept aims to address urban problems and solve them. The local government has been improving its public transportation service to reduce traffic congestion, air pollution, citizen mobility, etcetera. Dinas Bina Marga DKI Jakarta (a local government organization in charge of roads and public infrastructure) revitalizes public facilities such as pedestrian corridors to support public transportation. Dinas Bina Marga cooperates with the Institute for Transportation Development Policy (ITDP) Indonesia to plan a human mobility network in Jakarta and realize their vision to focus on pedestrian networks by improving public facilities for pedestrians and cyclists (ITDP, 2019).

Jalan Kyai Tapa, Jakarta, is a major road with two pedestrian corridors and green belts on the side. The traffic at Jalan Kyai Tapa is generally quite busy because this road is passed by several Transjakarta bus routes and is connected to other major roads. Quite a lot of people use pedestrian corridors at Jalan Kyai Tapa. However, in the afternoon, it may feel uncomfortable to walk there due to heat and sunlight exposure, and significant coverages of pavements worsen that. The thermal condition of a pedestrian corridor is essential to create a comfortable walking experience. Considering the local government's goal to improve the pedestrian corridors, we need to understand the current conditions of pedestrian corridors in Jakarta in terms of their thermal comfort. Pedestrian comfort has been widely studied overseas but is still relatively limited in Indonesia. Existing studies have analyzed pedestrian corridors' comfort in Indonesia cities concerning its users' preferences (Illiyin & Alprianti, 2017), perception (Budiarto et al., 2019), and facilities quality (Krisnaputri et al., 2023). Only a few studies specifically focus on the thermal comfort of pedestrian corridors and analyze it quantitatively (Febriarto, 2016). Even fewer studies exist on the thermal comfort of pedestrian corridors in Jakarta. Studies on pedestrian corridors in Jakarta primarily relate to transit-oriented development concepts (Mulyadi, 2020; Wulanningrum, 2021). More quantitative research on the thermal comfort of pedestrian corridors in Jakarta is needed. This study analyzes the thermal comfort of pedestrian corridors at Jalan Kyai Tapa concerning its landscape composition, including vegetation structure and pavement. By analyzing the existing thermal condition of pedestrian corridors at Jalan Kyai Tapa, this study can briefly illustrate other pedestrian corridors with a similar condition in Jakarta. Hopefully, this study can help improve the pedestrian corridors in Jakarta.

2. Methods

2.1 Study area

The study area is two pedestrian corridors at Jalan Kyai Tapa, Grogol, West Jakarta. Jalan Kyai Tapa is a significant road passed by several Transjakarta routes and is connected to other major roads, such as Jalan Letjen S. Parman and Jalan Daan Mogot (Figure 1). There are two sides of pedestrian corridors at Jalan Kyai Tapa: (1) the terminal side (north side) and (2) the university side (south side).

The terminal side has a bus terminal, police station, and traffic gardens. Meanwhile, university buildings, hotels, restaurants, and other commercial buildings are on the university side. The tree information in the study area is collected for further analysis. When inventorying vegetation, existing studies created plots of 100 meters by 100 meters in broad areas, such as national parks (Haryadi et al., 2019; Maulidiyan et al., 2019), and created belt transects of 100 m in linear areas, such as roadsides (Danniswari & Nasrullah, 2017). Therefore, we divided the 300-meter-long pedestrian corridors into three segments, 100 m-long each. The study area and the segmentation are shown in Figure 2. The field data was collected from November 2021 until February 2022.

2.2 Data collection

The study is conducted quantitatively. We collect data on field air temperature, relative humidity, wind speed, tree species, tree height, and canopy diameter. Air temperature, relative humidity, and wind speed measurement points are distributed along the corridors. The measurement is done three times daily at 08:00, 12:00, and 16:00 for seven days during sunny weather using a digital thermohygrometer. The pedestrian corridors have two sides, the university side and the terminal side, with a length of 300 m. We observed both corridors and divided each corridor into three segments 100 m long. Table 1 shows the location and measurement point at each corridor side. The number of measurement points at the terminal side is fewer due to the smaller vegetation coverage on this side.

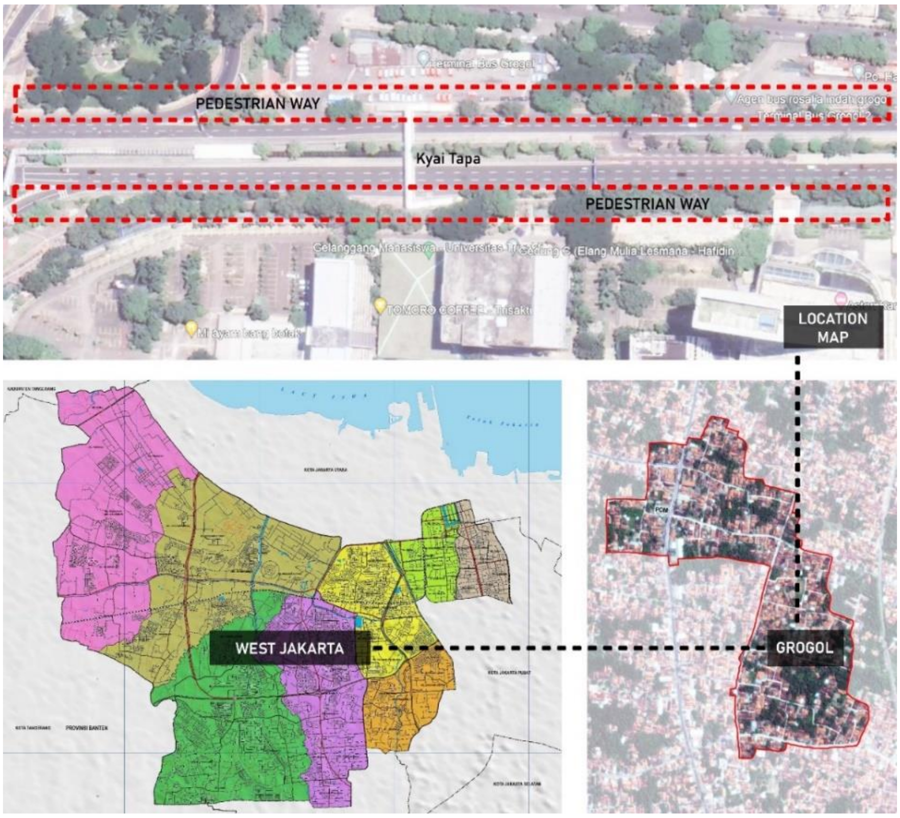

Figure. 1 Study location map

Figure. 2 Study area, the pedestrian corridors at Kyai Tapa, and the segmentation

2.3 Data analysis

The data are analyzed to calculate the Temperature Humidity Index. The THI is estimated to determine the equivalent temperature perceived by humans by considering the air temperature and relative humidity. This index has been widely used to measure the human body's comfort (Isnoor et al., 2021; Putri et al., 2021; Rusdayanti et al., 2021).

Table 1. Location and measurement points

Pedestrian corridor side	Location	Total Length (m)	Segment length (m)	Total measurement points	Measurement points per segment
University side	May 12th Monument to Aston Hotel	300	100	27	8-11
Terminal side	Flyover garden to Terminal garden	300	100	16	5-6

Measured field air temperature and humidity are calculated following the THI formula by McGregor & and Nieuwolt (1998), shown in Equation 1. Where: *THI* = Temperature Humidity Index (°C), *T* = Air Temperature (°C), *RH* = Relative Humidity (%).

$$THI = 0.8\,T + (RH \times T)/500 \quad (1)$$

Table 2 shows the categories for THI values. The categories of THI used in this study follow the categories made by McGregor & Nieuwolt (1998) and Emmanuel (2005), which are modified by Effendy (2007) for tropical climate use. Ideal environments perceived as comfortable by humans fall in the range of 27-28 °C for temperature and 40-75% for relative humidity (Laurie, 1975).

Table 2. THI value categories

THI value (°C)	Category
$21 \geq THI \leq 24$	Comfortable
$25 \geq THI \leq 27$	Less comfortable
$THI > 27$	Not comfortable

3. Results and discussions

3.1 The structure of vegetation

There are two sides of pedestrian corridors at Jalan Kyai Tapa: university and terminal. Each side is divided into three segments. At segment I of Jalan Kyai Tapa, university side, 30 trees comprise six species. The canopy diameter varies from 1.5 – 6.4 m, and the height varies from 3.75 – 9.6 m. The most common species are *Mimusops elengi* and *Ficus virens*, each of 11 trees. There are five trees of *Casuarina equisetifolia*, 2 of Artocarpus heterophyllus, and 1 of *Cerbera manghas*. The vegetation structure of segment I, the university side, is shown in Table 3.

In segment II, there are a total of 17 trees that consist of 5 different species, which are seven trees of *Ficus virens*, six trees of *Mimusops elengi*, two trees of *Cerbera mangas*, one tree of *Samanea saman*, and one tree of *Muntingia calabura*. The canopy diameter at segment II ranges from 3 – 9 m, and the tree height from 3.2 – 11.2 m. The vegetation structure of segment II is summarized in Table 4. Segment III has the highest number of trees compared to Segment I and II. There are 37 trees of 7 species with the canopy diameter varying from 3.2 – 7 m and the tree height ranging from 6 – 9 m. This segment is dominated by *Ficus virens* of 20 trees, *Mimusops elengi* of 5 trees, *Casuarina equsetifolia* of 9 trees, *Cerbera manghas* of 2 trees, and *Samanea saman* of 1 tree. The vegetation structure of segment III is shown in Table 5.The number of trees at the terminal side is fewer than at the university side because the pedestrian corridor is disconnected at several points due to the entrance/exit way for vehicles to or from the terminal.

Table 3. Vegetation structure at segment I, university side

Segment	Point	Tree Name		Tree Size (m)		Number
		Local Name	Scientific Name	Canopy Diameter	Height	
I	T1	-	-	-	-	-
	T2	Tanjung	*Mimusops elengi*	4.8	9.0	2
	T3	Tanjung	*Mimusops elengi*	4.8	9.0	2
		Ficus	*Ficus virens*	6.4	5.0	1
	T4	Ficus	*Ficus virens*	6.4	3.8	1
	T5	Nangka	*Artocarpus heterophyllus*	4.8	9.0	1
		Tanjung	*Mimusops elengi*	4.8	9.0	1
		Bintaro	*Cerbera manghas*	3.6	7.0	1
	T6	Ficus	*Ficus virens*	6.4	9.6	1
		Tanjung	*Mimusops elengi*	1.5	4.5	1
	T7	Ficus	*Ficus virens*	6.4	9.6	1
		Tanjung	*Mimusops elengi*	1.5	4.5	1
		Cemara angin	*Casuarina equisetifolia*	2.4	6.4	1
	T8	Ficus	*Ficus virens*	6.4	9.6	1
		Tanjung	*Mimusops elengi*	1.5	4.5	1
		Cemara angin	*Casuarina equisetifolia*	2.4	6.4	1
	T9	Ficus	*Ficus virens*	6.4	9.6	2
		Cemara angin	*Casuarina equisetifolia*	2.4	6.4	1
		Nangka	*Artocarpus heterophyllus*	4.8	9.0	1
		Tanjung	*Mimusops elengi*	1.5	4.5	1
	T10	Cemara angin	*Casuarina equisetifolia*	2.4	6.4	2
		Ficus	*Ficus virens*	6.4	9.6	1
	T11	Ficus	*Ficus virens*	6.4	9.6	3
		Tanjung	*Mimusops elengi*	1.5	4.5	2

Table 4. Vegetation structure at segment II, university side

Segment	Point	Tree Name		Tree Size (m)		Number
		Local Name	Latin Name	Canopy Diameter	Height	
II	T12	Ficus	*Ficus virens*	4.8	5.8	1
		Tanjung	*Mimusops elengi*	3.2	6.4	2
		Ficus	*Ficus virens*	3.5	4.5	1
	T13	Ficus	*Ficus virens*	6.4	9.0	1
	T14	Bintaro	*Cerbera manghas*	3.6	7.0	1
		Ficus	*Ficus virens*	6.4	9.0	1
	T15	Ficus	*Ficus virens*	6.4	9.0	1
		Bintaro	*Cerbera manghas*	3.0	7.0	1
		Trembesi	*Samanea saman*	9.0	11.2	1
	T16	-	-	-	-	-
	T17	Tanjung	*Mimusops elengi*	3.2	4.8	1
		Kersen	*Muntingia celabura*	3.2	3.2	1
	T18	Tanjung	*Mimusops elengi*	3.2	4.8	1
		Ficus	*Ficus virens*	3.2	4.0	1
		Tanjung	*Mimusops elengi*	3.2	6.4	1
	T19	Ficus	*Ficus virens*	5.6	9.0	1
		Tanjung	*Mimusops elengi*	3.2	6.4	1
	T20	Cemara angin	*Casuarina equisetifolia*	3.2	6.9	1

At segment I of the Terminal side, there are 21 trees of 5 species whose canopy diameter varies from 3 – 5 m and the height varies from 6 – 10.8 m. This segment has 14 trees of

Handroanthus chrysotrichus, three trees of *Swietenia mahagoni*, one tree of *Samanea saman*, one tree of *Casuarina equisetifolia*, and one tree of *Pterocarpus indicus*.

Table 5. Vegetation structure at segment III, university side

Segment	**Point**	**Tree Name**		**Tree Size (m)**		**Number**
		Local Name	**Latin Name**	**Canopy Diameter**	**Height**	
III	T21	Trembesi	*Samanea saman*	7.5	7.5	1
		Cemara angin	*Casuarina equisetifolia*	3.2	6.9	1
	T22	Ficus	*Ficus virens*	5.6	9.0	1
		Cemara angin	*Casuarina equisetifolia*	3.0	8.3	1
		Bintaro	*Cerbera manghas*	3.0	7.0	1
	T23	Ficus	*Ficus virens*	3.8	6.0	2
	T24	Ficus	*Ficus virens*	3.8	6.0	3
		Cemara angin	*Casuarina equisetifolia*	3.0	8.3	1
		Tanjung	*Mimusops elengi*	3.0	7.5	1
	T25	Ficus	*Ficus virens*	3.8	6.0	7
		Tanjung	*Mimusops elengi*	3.0	7.5	2
		Cemara angin	*Casuarina equisetifolia*	4.5	8.3	1
	T26	Ficus	*Ficus virens*	3.8	6.0	6
		Cemara angin	*Casuarina equisetifolia*	3.0	8.3	2
		Tanjung	*Mimusops elengi*	4.5	7.5	1
		Bintaro	*Cerbera manghas*	3.0	7.0	1
	T27	Cemara angin	*Casuarina equisetifolia*	3.0	8.3	2
		Ficus	*Ficus virens*	6.4	9.0	1
		Tanjung	*Mimusops elengi*	4.5	7.5	1

In segment II, there are only three trees: 2 of Casuarina equisetifolia and 1 of *Pterocarpus indicus*. In segment III, seven trees consist of 7 of *Pterocarpus indicus*, 2 of Casuarina equisetifolia, and 1 of *Ficus benjamina*. The canopy diameter varies from 2 – 4 m, and the height varies from 10 – 11 m. The vegetation structure of the Terminal side is shown in Table 6.

Table 6. Vegetation structure at segment I, II, III, terminal side

Segment	Point	Tree Name		Tree Size (m)		Number
		Local Name	Latin Name	Canopy Diameter	Height	
I	T1	Tabebuya	*Handroanthus chrysotrichus*	3.0	6.0	1
		Trembesi	*Samanea saman*	5.0	10.0	1
	T2	Tabebuya	*Handroanthus chrysotrichus*	3.0	6.0	10
	T3	Tabebuya	*Handroanthus chrysotrichus*	3.0	6.0	3
	T4	Cemara angin	*Casuarina equisetifolia*	4.0	11.0	1
		Mahoni	*Swietenia mahagoni*	3.0	10.0	3
	T5	Angsana	*Pterocarpus indicus*	3.0	10.8	2
II	T6	-	-	-	-	-
	T7	-	-	-	-	-
	T8	Cemara angin	*Casuarina equisetifolia*	4.0	11.0	1
	T9	Cemara angin	*Casuarina equisetifolia*	2.0	11.0	1
	T10	-	-	-	-	-
	T11	Angsana	*Pterocarpus indicus*	4.0	10.8	1
III	T12	Angsana	*Pterocarpus indicus*	4.0	10.8	1
	T13	Angsana	*Pterocarpus indicus*	4.0	10.8	2
	T14	Angsana	*Pterocarpus indicus*	4.0	10.8	2
	T15	Angsana	*Pterocarpus indicus*	2.0	11.0	1
	T16	Beringin	*Ficus benjamina*	2.0	10.0	1

In previous studies, a more expansive tree canopy and thicker leaves can help reduce air temperature and improve microclimate (Hanifah & Yulita, 2018). Trees with wider crown diameters provided a larger shaded area, improving thermal comfort (Boukhabla & Alkama, 2012). The most influential parameter affecting outdoor thermal comfort is leaf area index (LAI), followed by trunk height, tree height, and crown diameter (Morakinyo et al., 2018). Tall trees with an extensive leaf area index and canopy diameter (> 6 meters) should be prioritized when selecting trees to improve outdoor comfort (Zhang et al., 2018). The diameter of the tree canopy in the study area is mostly less than 5 meters. This length may not be extensive enough to improve air temperature adequately.

3.2 The thermal environment

The air temperature and relative humidity of Jalan Kyai Tapa are measured at 27 points on the university side and 16 points on the terminal side. At the university side (Figure 3), the average air temperature at 08:00 ranges from 30.16-31.29°C.

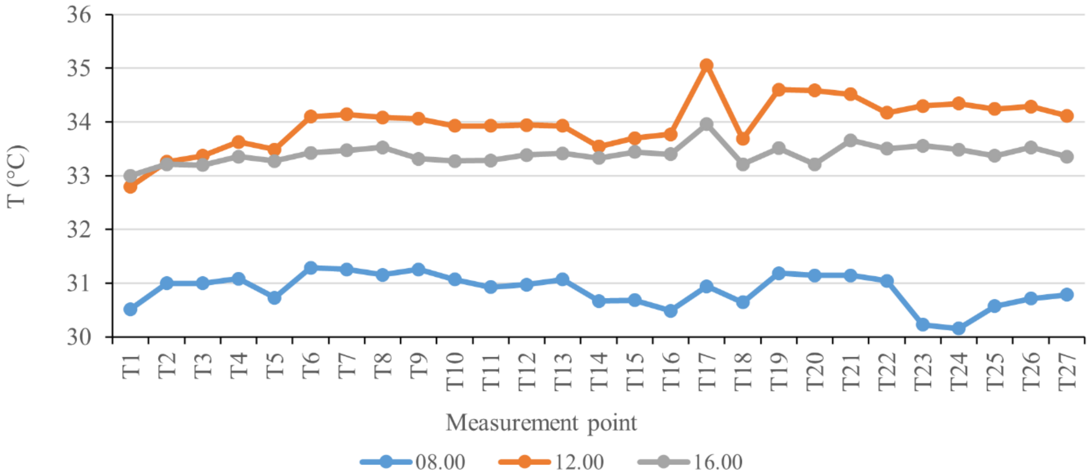

Figure. 3 The average temperature of Jalan Kyai Tapa, university side

At 08:00, the lowest air temperature is found at T24 (segment II), and the highest is found at T6 (segment I). The average air temperature at 12:00 ranges from 32.8-35.1°C. The lowest air temperature is T1 (segment I), and the highest is T17 (segment II). The average air temperature at 16:00 ranges from 33-34 °C. The lowest air temperature is T1 (segment I), and the highest is T17 (segment II). The average air temperatures measured at 08:00, 12:00, and 16:00 are considered less comfortable for human activities.

At the terminal side (Figure 4), the average air temperature at 08:00 ranges from 30.07-31.33°C. The lowest air temperature is found at T1 (segment I), and the highest is at T9 (segment II). The average air temperature at 12:00 ranges from 33.71-36.03 °C; the lowest is at T1 (segment I), and the highest is at T9 (segment II). The average air temperature at 16:00 ranges from 33.37-34.67 °C, the lowest at T1 (segment I) and the highest at T9 (segment II). Although the air temperature ranges differ in three observed times, all three segments' lowest air temperature is found at T1 and the highest at T9. Based on these values, the air temperature of the terminal side at 08:00, 12:00, and 16:00 is considered less comfortable for humans.

Figure 5 shows the average relative humidity measured at the university side. The average relative humidity at 08:00 ranges from 71.99 – 75.94%, the lowest at T26 (segment II) and the highest at T18 (segment II). This temperature is categorized as less comfortable for humans.

At 12:00, the average relative humidity ranges from 56.21 – 61.46%, the lowest at T26 (segment II) and the highest at T9 (segment I). At 16:00, the average relative humidity ranges from 62.7 – 65%; the lowest is at T17 (segment II), and the highest is at T4 (segment I). The average relative humidity at 12:00 and 16:00 is considered comfortable for humans.

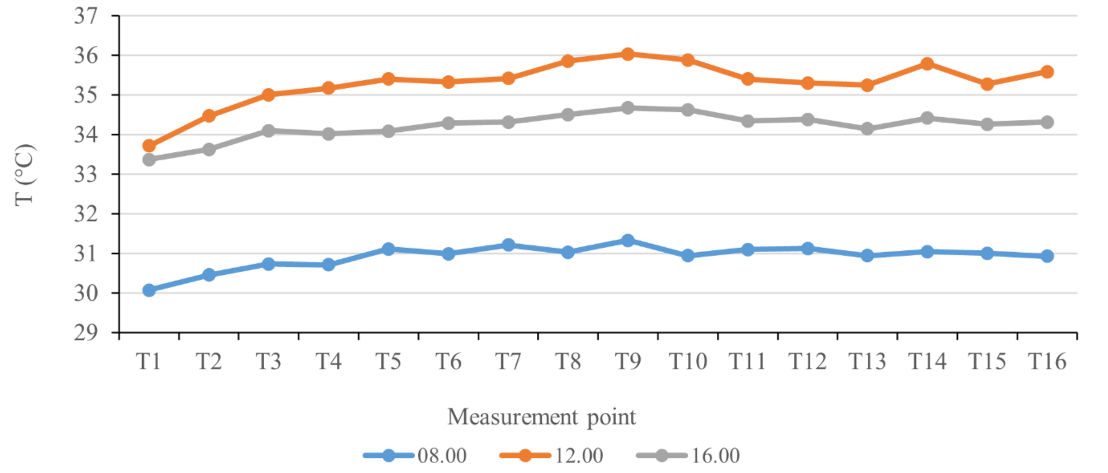

Figure. 4 The average temperature of Jalan Kyai Tapa, terminal side

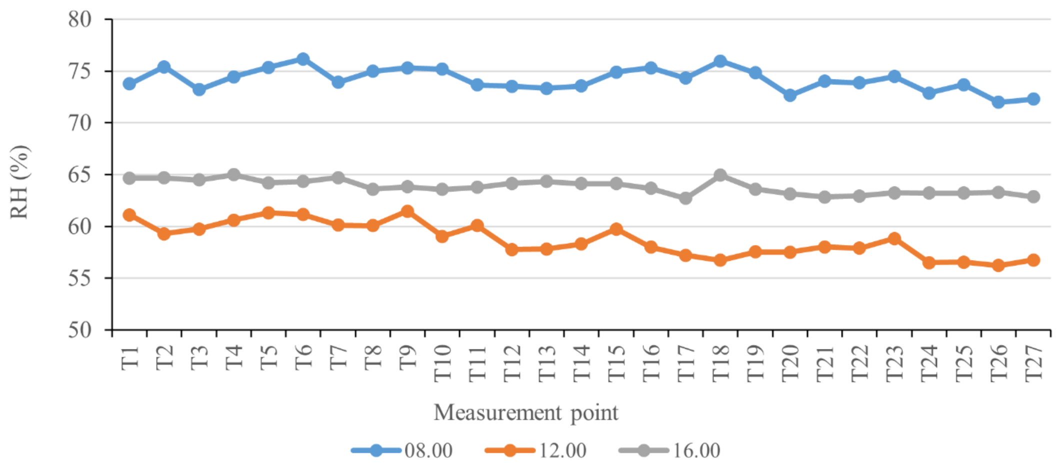

Figure. 5 Average relative humidity of Jalan Kyai Tapa, university side

The average relative humidity measured at the terminal side is shown in Figure 6. The average relative humidity at 08:00 ranges from 71.19 – 73.10%, the lowest at T10 (segment I) and the highest at T4 (segment I). This temperature is categorized as less comfortable for humans. At 12:00, the average relative humidity ranges from 56.0 – 61.4%, the lowest at T14 (segment III) and the highest at T1 (segment I). At 16:00, the average relative humidity ranges from 60.74 – 64.3%, the lowest at T7 (segment II) and the highest at T1 (segment I). The average relative humidity at 12:00 and 16:00 is considered comfortable for humans.

Additionally, we measured the wind speed at the university side (Figure 7) and terminal side (Figure 8) of Jalan Kyai Tapa. Generally, the average wind speed at the terminal side is slightly higher than the university side, possibly due to fewer trees at the terminal side. At the terminal side, the average is 33.41 km/hour; at the university, the average is 32.86 km/hour.

According to the Beaufort Scale (Stewart, 2008), a 29-38 km/hour wind speed is considered a fresh breeze. Both sides show a similar tendency where the highest wind speed is found at 12:00, and the lowest is at 08:00. Although wind speed does not influence the THI, the existence of wind can improve perceived human thermal comfort.

In previous studies, canopy shape is essential in distributing air temperature (Fabbri et al., 2017). Shade from the tree canopy affects plant evapotranspiration, which increases relative humidity and absorbs heat energy, leading to decreased air temperature (Perini et al., 2018) and decreased soil temperature (Morakinyo et al., 2018). At T1 on the university side, although there were no trees, the average air temperature was lowest, and at T17, it was highest at 12:00 and

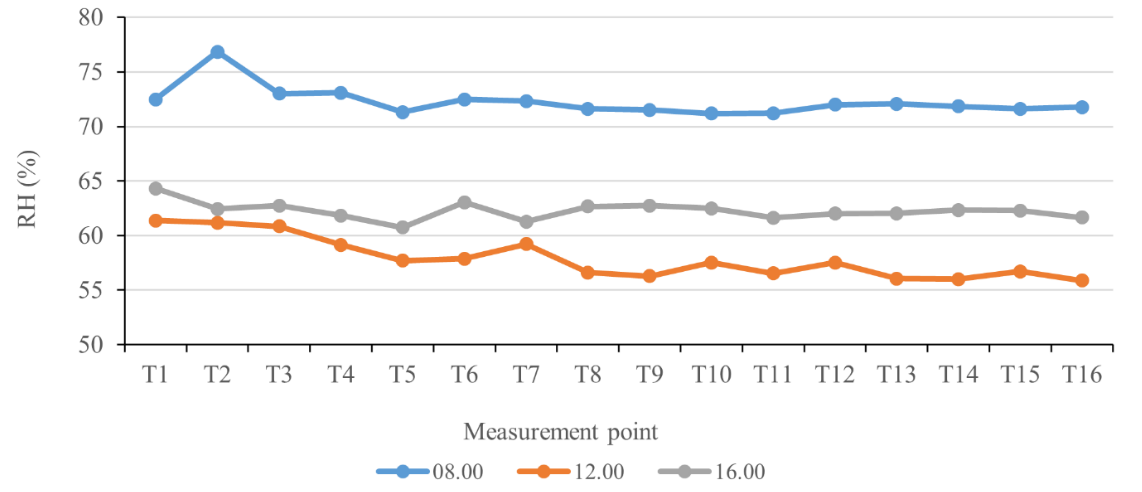

Figure. 6 Average relative humidity of Jalan Kyai Tapa, terminal side

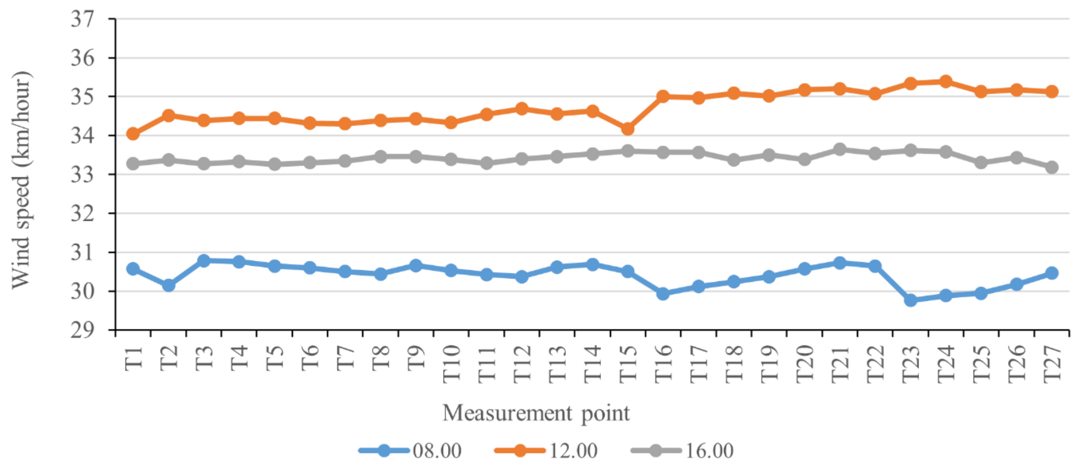

Figure. 7 Average wind speed of Jalan Kyai Tapa, university side

16:00, despite the presence of *Mimusops elengi* trees. However, at 08:00, T24 had the lowest temperature, and T6 had the highest. T6 and T24 had *Ficus virens* and *Mimusops elengi* trees nearby, but there were more trees in T24.

The different trends between the morning (08:00) and afternoon (12:00 and 16:00) observations are likely related to the evapotranspiration activity of the trees throughout the day. Evapotranspiration is driven by solar radiation, and its rate increases rapidly in the morning, especially from 07:00 to 10:00, which may cause the cooling benefits of trees in the morning to be more pronounced than in the afternoon (Sharmin et al., 2023).

3.3 Temperature heat index

We estimate the average THI at the university and terminal sides based on the measured air temperature and relative humidity in the study area. The average THI of the university side (Figure 9) at 08:00 ranges from 28.5-29.8 °C, with the lowest average THI found at T24 (segment III) and the highest at T6 (segment I). At 12:00, the average THI ranges from 30.2-31.6 °C; the lowest is T1 (segment I), and the highest is T20 (segment III). The average THI at 16:00 ranges from 30.6-31.4 °C; the lowest is T1 (segment I), and the highest is T17 (segment II). The average THI at 08:00, 12:00, and 16:00 is considered uncomfortable. The most uncomfortable time is at 12:00.

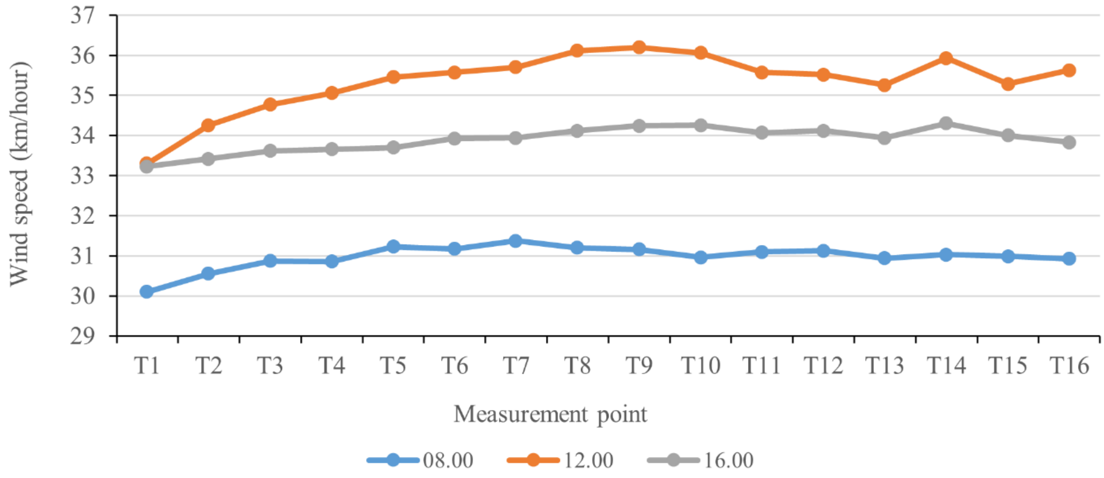

Figure. 8 Average wind speed of Jalan Kyai Tapa, terminal side

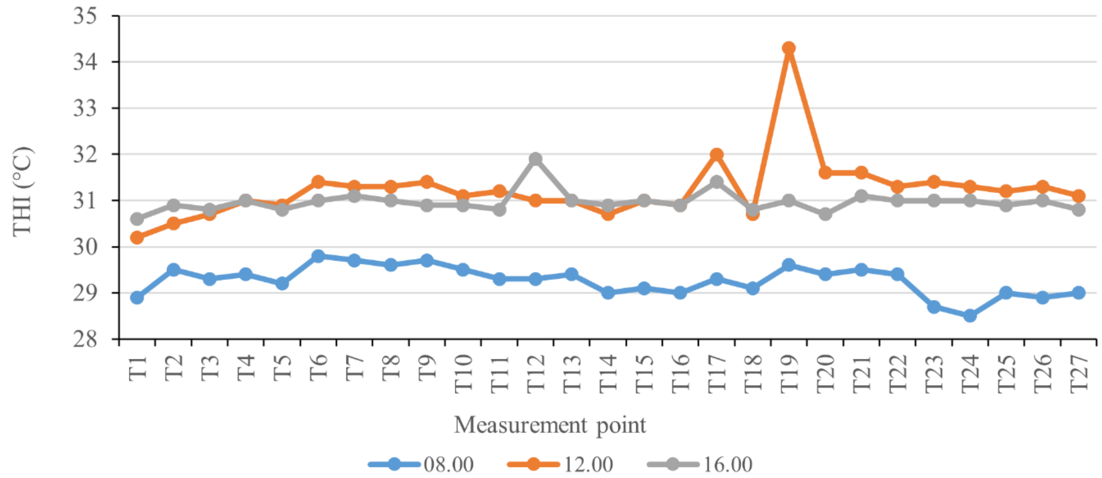

Figure. 9 The average THI on the university side

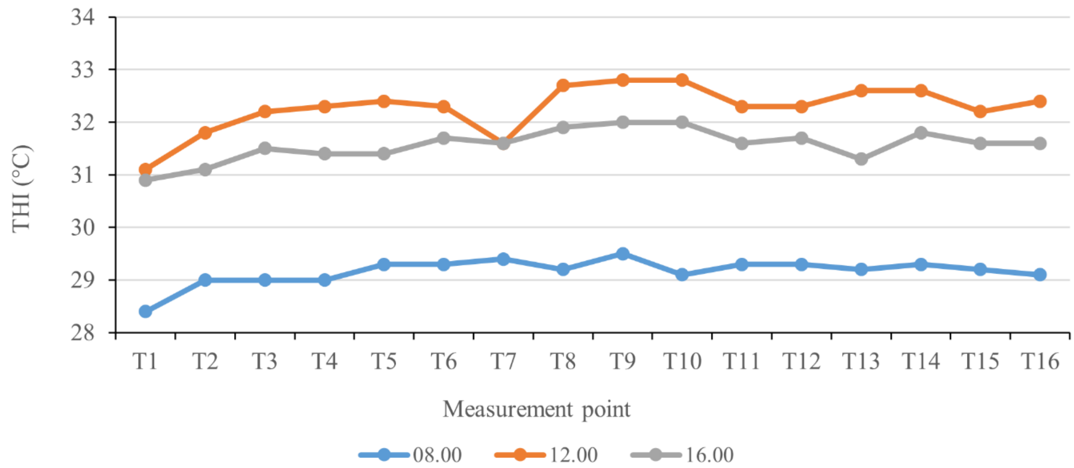

Figure. 10 The average THI at the terminal side

Figure 10 shows the average THI at the terminal side. The average THI at 08:00 ranges from 28.4-29.5 °C, with the lowest THI at T1 (segment I) and the highest at T9 (segment II). At 12:00, the average THI ranges from 31.1 – 32.8 °C; the lowest is at T1 (segment I), and the highest is at T9 and T10 (segment II). The average THI at 16:00 ranges from 30.9-32.0 °C; the lowest is at T1 (segment I), and the highest is at T9 and T10 (segment II). The average THI at 08:00,

DOI: https://doi.org/10.7454/jessd.v6i2.1201

12:00, and 16:00 is considered uncomfortable. Like the university side, the most uncomfortable time is at 12:00.

3.4 Factors that influence thermal comfort

According to the results, at the university side segments I, II, and II, there are 84 trees with varying canopy diameters from 1.5 – 9.0 m and varying heights from 3.2 – 11.2 m. Meanwhile, at the terminal side segments I, II, and II, there are 31 trees with varying canopy diameters from 2.0 – 5.0 m and varying heights from 6.0 – 11.0 m. Trees at Jalan Kyai Tapa have relatively wide canopy diameters. Trees with wide canopy diameters provide more expansive shaded areas, improving thermal comfort (Boukhabla & Alkama, 2012). More expansive tree canopy and denser leaves can help reduce air temperature and improve microclimate (Hanifah & Yulita, 2018). However, based on the THI results, the trees at Jalan Kyai Tapa's pedestrian corridors do not seem to adequately improve the air temperature and relative humidity to reach a comfortable state for pedestrians.

Several factors possibly caused the uncomfortable THI results of this study. Generally, the effectiveness of vegetation affecting outdoor microclimate is determined by five main parameters: foliage shape and dimensions, trunk height, leaf area density, seasonal cycle, and daily transpiration (Perini et al., 2018). The shape of a tree canopy is essential in distributing air temperature (Fabbri et al., 2017). The shade from the tree canopy influences the plants' evapotranspiration, increasing relative humidity and absorbing thermal energy that decreases air temperature (Perini et al., 2018) and decreases the ground temperature (Morakinyo et al., 2018). An existing study found that the most influential parameter affecting outdoor thermal comfort is leaf area index (LAI), followed by trunk height, tree height, and crown diameter (Morakinyo et al., 2018). LAI is a one-sided green leaf area per unit ground area (Wu et al., 2020). Another study suggests that tree arrangement (height-to-distance ratio of trees) is also essential because the arrangement influences wind speed and sunlight blockade (Zhang et al., 2018). The same study mentioned that large LAI is likely more significant than canopy diameter and tree height.

Furthermore, tall trees with an extensive leaf area index and canopy diameter (> 6 meters) should be prioritized when selecting trees to improve outdoor comfort (Zhang et al., 2018). Vegetation in its best condition can decrease air temperature up to 3.5 °C (Wang & Akbari, 2016). Concerning the results of this study, the trees' canopy diameter in the study area might not be wide enough to provide adequate improvement to the air temperature, considering the majority of the tree's canopy diameter is less than 5 meters. However, this study does not investigate the LAI of each tree, which was found to be the most influential parameter in existing studies. Further studies on LAI and tree arrangements are required to more accurately determine the cause of uncomfortable outdoor areas.

Many studies analyzed how urban trees can benefit human thermal comfort. Trees can alleviate urban air temperature, but not all are equally effective (Richards et al., 2020). Some studies suggest that taller trees have a better performance at improving street thermal comfort (Manickathan et al., 2018; Yang et al., 2018). It may be related to how taller trees can pass through incoming airflow horizontally and remarkably improve pedestrian wind comfort (Kang et al., 2020). This condition is similar to what we found during field measurement at the university side, where some spots under *Casuarina equisetifolia* trees that can pass wind have lower THI (better thermal comfort) than some spots under *Mimusops elengi* trees that tend to have dense canopy. An existing study suggests that trees with a large canopy, short trunk, and dense canopy can reduce mean radiant temperature effectively (Kong et al., 2017).

Interestingly, we found that T1 has the lowest average air temperature at the university side, and T17 has the highest temperature at 12:00 and 16:00. However, there is no tree at T1. There is a *Mimusops elengi* tree at T17. However, the tendency is different at 08:00. At 08:00, T24 has *virens* and *Mimusops elengi* nearby, but the number of trees is more significant at T24. The different tendency between morning observation (08:00) and afternoon observations (12:00 and 16:00) is possibly related to the evapotranspiration activity of the trees across the day. Evapotranspiration is driven by solar radiation, and the rate increases rapidly in the morning, especially from 07:00 to 10:00, which may cause trees' cooling benefits in the morning to be more apparent than in the afternoon (Sharmin et al., 2023). The difference between evapotranspiration rates in the morning and afternoon likely causes the difference in tendency between morning and afternoon observations. As for the afternoon phenomenon, where T1 (no tree) has the lowest average air temperature, and T17 (with tree) has the highest, possible canopy-associated warming occurred during observations. Sharmin et al. (2023) conducted a study to determine the cooling benefits of 10 urban tree species considering the tree traits and microclimatic conditions in suburban areas. The study found that there was canopy-associated warming in the afternoon, and it continued overnight. In the afternoon, the average temperature under the tree canopy increases by 1.19 °C compared to ambient air temperature. Meanwhile, at night, the average temperature increases 1.53 °C. Among the observed species in that study, the species with the highest LAI has the lowest sub-canopy warming effect. The heat from nearby buildings can also cause the sub-canopy warming effect. A study by Alonzo et al. (2021) conducted in Washington DC found that trees along streets have a less cooling effect than trees surrounded by grass or other vegetation due to re-radiated heat from under-tree canopy and surrounding surfaces. This condition further supports that the air temperature under trees might be higher than the ambient air temperature, mainly if buildings like the study area surround the area. This condition may also explain why such a phenomenon is not found on the terminal side, considering the terminal side has fewer structures and buildings than the university side. On a side note, it is worth noting that T1 is also located near a small water body, which may also help decrease the air temperature due to water body evaporation (Chen et al., 2023).

In another case, T9 of the terminal side shaded by *Casuarina equisetifolia* consistently has the highest air temperature at 08:00, 12:00, and 16:00, and also the highest THI (worst thermal comfort). The tree is not a shade tree and only has a canopy diameter of 2 meters. Furthermore, the planting distance between trees in that area is larger than the canopy diameter, so we suggest it cannot provide the proper shade to cool down the air temperature. We mentioned that some spots with Casuarina equisetifolia at the university have better thermal comfort than *Mimusops elengi*. This condition indicates that vegetation species alone cannot determine thermal comfort. It is also related to the planting distance, design, and other elements close to it. The planting design and the vegetation type must be considered according to the intended usage of the space (Meili et al., 2021).

Generally, the university side has better thermal comfort than the terminal side. The university side also has more trees and less pavement coverage than the terminal. Trees can improve thermal comfort, and to optimize tree function in pedestrian corridors, we should consider tree characteristics and arrangement. From the results of this study, we discussed that various factors and the trees determine the thermal comfort of pedestrian corridors' influence on microclimate, which can be different depending on the time of the day. Our findings offer the thermal comfort overview of pedestrian corridors in Jakarta during the morning and afternoon, which was not sufficiently explored in existing studies. This research still has limitations, specifically in measuring LAI and the distance between trees. Therefore, further research is required before proposing recommended planting designs and plant selection that can improve people's thermal comfort, such as reducing air temperature, adjusting relative humidity, and creating a wind corridor.

4. Conclusion

The findings of this study show that the air temperature of Jalan Kyai Tapa ranges from 31.01-31.54°C and the relative humidity ranges from 56.19 – 57.74%. The average air temperature and relative humidity at Jalan Kyai Tapa are 31.2°C and 57%, respectively. The average THI at Jalan Kyai Tapa is 28.52°C, which is categorized as uncomfortable. In areas with small tree spacing, the air temperature tends to be low, and the relative humidity tends to be high. On the contrary, in areas with large tree spacing, the air temperature tends to be high, and the relative humidity tends to be low. Although many trees at Jalan Kyai Tapa have relatively large canopies, they do not adequately improve the air temperature and relative humidity to make the corridor thermally comfortable for pedestrians. Trees might not be the most influential factor in improving pedestrian thermal comfort, as we found a measurement point with no tree with the lowest temperature in the afternoon. Further research about the impact of tree arrangement, tree selection, and hardscape structure on thermal comfort is necessary to optimize the roadside greenbelt design for creating comfortable pedestrian corridors.

Acknowledgment
We express our gratitude and appreciation to the Lembaga Penelitian Universitas Trisakti, who have supported this research implementation's funds.

Author Contribution
Conceptualization, N.I.S.; Methodology, N.I.S.; Analysis, N.I.S., D.D., R.F.; Investigation, N.I.S., R.F.; Writing – Original Draft Preparation, N.I.S.; Writing – Review & Editing, R.F., D.D., R.F.; and Funding Acquisition, N.I.S.

References
Achour-Younsi, S., & Kharrat, F. (2016). Outdoor thermal comfort: impact of the geometry of an urban street canyon in a mediterranean subtropical climate – case study Tunis, Tunisia. *Procedia - Social and Behavioral Sciences, 216*, 689–700. https://doi.org/10.1016/j.sbspro.2015.12.062

Alonzo, M., Baker, M. E., Gao, Y., & Shandas, V. (2021). Spatial configuration and time of day impact the magnitude of urban tree canopy cooling. *Environmental Research Letters*, *16*(8). https://doi.org/10.1088/1748-9326/ac12f2

Badan Pusat Statistik (BPS). (2021, January 22). Hasil sensus penduduk 2020 - DKI Jakarta. *Badan Pusat Statistik. https://jakarta.bps.go.id/pressrelease/2021/01/22/541/jumlah-penduduk-hasil-sp2020-provinsi-dki-jakarta-sebesar-10-56-juta-jiwa.html*

Baldauf, R. (2020). Air pollution mitigation through vegetation barriers and green space. *Traffic-Related Air Pollution* (pp. 437–453). Elsevier. https://doi.org/10.1016/B978-0-12-818122-5.00017-X

Biao, Z., Wenhua, L., Gaodi, X., & Yu, X. (2010). Water conservation of forest ecosystem in Beijing and its value. *Ecological Economics*, *69*(7), 1416–1426. https://doi.org/10.1016/j.ecolecon.2008.09.004

Boukhabla, M., & Alkama, D. (2012). Impact of vegetation on thermal conditions outside, thermal modeling of urban microclimate, case study: The street of the republic, Biskra. *Energy Procedia*, *18*, 73–84. https://doi.org/10.1016/j.egypro.2012.05.019

Budiarto, A., Nurhikmah, N., & Purnomo, A. B. (2019). Persepsi pejalan kaki dengan keberadaan pedestrian di path studi kasus: Kawasan Pasar Minggu, Jakarta. *Jurnal Penelitian Dan Karya Ilmiah Lembaga Penelitian Universitas Trisakti*, *4*(1), 41–46. https://doi.org/10.25105/pdk.v4i1.4029

Cabral, J., Morzillo, A. T., & Xu, R. (2023). Forest stressors and roadside vegetation management in an exurban landscape. *Urban Forestry & Urban Greening*, *85*, 127954. https://doi.org/10.1016/j.ufug.2023.127954

Cai, Y., Li, C., Ye, L., Xiao, L., Gao, X., Mo, L., Du, H., Zhou, Y., & Zhou, G. (2022). Effect of the roadside tree canopy structure and the surrounding on the daytime urban air temperature in summer. *Agricultural and Forest Meteorology*, *316*, 108850.

https://doi.org/10.1016/j.agrformet.2022.108850
Chen, H., Jeanne Huang, J., Li, H., Wei, Y., & Zhu, X. (2023). Revealing the response of urban heat island effect to water body evaporation from main urban and suburb areas. *Journal of Hydrology*, 129687. https://doi.org/10.1016/j.jhydrol.2023.129687
Childers, D. L., Bois, P., Hartnett, H. E., McPhearson, T., Metson, G. S., & Sanchez, C. A. (2019). Urban ecological infrastructure: An inclusive concept for the non-built urban environment. *Elementa*, *7*(1). https://doi.org/10.1525/elementa.385
Danniswari, D., & Nasrullah, N. (2017). Evaluation of roadside greenbelt trees damage caused by strangler plants in Bogor. *IOP Conference Series: Earth and Environmental Science*, *91*(1). https://doi.org/10.1088/1755-1315/91/1/012012
Departemen Pekerjaan Umum. (1996). Tata cara perencanaan teknik lanskap jalan. In *Direktorat Jendral Bina Marga*.
Effendy, S. (2007). *Keterkaitan Ruang Terbuka Hijau dengan Urban Heat Island Wilayah*. IPB (Bogor Agricultural University).
Emmanuel, R. (2005). Thermal comfort implications of urbanization in a warm-humid city: The colombo metropolitan region (CMR), Sri Lanka. *Building and Environment*, *40*(12), 1591–1601. https://doi.org/10.1016/j.buildenv.2004.12.004
Fabbri, K., Canuti, G., & Ugolini, A. (2017). A methodology to evaluate outdoor microclimate of the archaeological site and vegetation role: A case study of the Roman Villa in Russi (Italy). *Sustainable Cities and Society*, *35*, 107–133. https://doi.org/10.1016/j.scs.2017.07.020
Febriarto, P. (2016). *Tata hijau pada ruang jalan menuju kenyamanan termal iklim mikro di Surakarta*. 1–6.
Fischer, C., Hanslin, H. M., Hovstad, K. A., D'Amico, M., Kollmann, J., Kroeger, S. B., Bastianelli, G., Habel, J. C., Rygne, H., & Lennartsson, T. (2022). The contribution of roadsides to connect grassland habitat patches for butterflies in landscapes of contrasting permeability. *Journal of Environmental Management*, *311*, 114846. https://doi.org/10.1016/j.jenvman.2022.114846
Hanifah, M., & Yulita, E. N. (2018). Tata lanskap terhadap kenyamanan termal berdasarkan indeks THI pada Taman Singha Merjosari Kota Malang. *Jurnal Mahasiswa Jurusan Arsitektur*, *6*(4).
Haryadi, H., Sunarto, S., & Sugiyarto, S. (2019). Vegetation analysis of the secondary forest area of Mount Merapi National Park. *Jurnal Biodjati*, *4*(1), 50–57. https://doi.org/10.15575/biodjati.v4i1.4239
Illiyin, D. F., & Alprianti, R. R. (2017). Preferensi pejalan kaki terkait kondisi lingkungan untuk menciptakan kenyamanan termal di Jalan Rajawali Surabaya. *Prosiding Temu Ilmiah IPLBI 2017*, 67-72. https://doi.org/10.32315/ti.6.e067
Isnoor, K., Bramandika Putra, A., & Aristya Firmantari, M. (2021). Analisis kenyamanan termal berdasarkan temperature humidity index dan pengaruhnya terhadap curah hujan di Kota Tanjungpinang. *Buletin GAW Bariri*, *2*(1), 1–6. https://doi.org/10.31172/bgb.v2i1.32
ITDP. (2019). *Panduan desain fasilitas pejalan kaki: DKI Jakarta 2017-2022 (versi 2.0)* (Vol. 2019, Issue September 2019). https://www.itdp-indonesia.org/wp-content/uploads/2018/08/Panduan-Fasilitas-Pejalan-Kaki-di-Jakarta-v2.0.pdf
Kang, G., Kim, J. J., & Choi, W. (2020). Computational fluid dynamics simulation of tree effects on pedestrian wind comfort in an urban area. *Sustainable Cities and Society*, *56*(November 2019), 102086. https://doi.org/10.1016/j.scs.2020.102086
Kong, L., Lau, K. K. L., Yuan, C., Chen, Y., Xu, Y., Ren, C., & Ng, E. (2017). Regulation of outdoor thermal comfort by trees in Hong Kong. *Sustainable Cities and Society*, *31*, 12–25. https://doi.org/10.1016/j.scs.2017.01.018

Krisnaputri, N. A., Juliana, A., Sembiring, E. T. J., Gabriella, G., Marvin, H., Gabriel, C., &

Caesar, B. (2023). Peningkatan kualitas jalur pejalan kaki melalui pendekatan kenyamanan dalam konsep TOD di sekitar Pasar Grogol. *Journal of Architecture Innovation*, *6*(2), 144–160. https://doi.org/10.36766/aij.v6i2.337

Laurie, M. (1975). *An Introduction to Landscape Architecture*. American Elsevier Pub. Co.

Manickathan, L., Defraeye, T., Allegrini, J., Derome, D., & Carmeliet, J. (2018). Parametric study of the influence of environmental factors and tree properties on the transpirative cooling effect of trees. *Agricultural and Forest Meteorology*, *248*(October 2017), 259–274. https://doi.org/10.1016/j.agrformet.2017.10.014

Maulidiyan, D., Ariansyah, E. N., Zubaidah, S., Widiastuti, E., Bekti, H. S., Larasati, A. D., Sari, R., Trijunianto, A., Aziz, S., Diany, E., Lestari, K. G., Muyasara, J. Q. D., Nurbayadi, Kurnianto, W., Hakim, L., & Hilwan, I. (2019). Vegetation structure and composition on rafflesia zollingeriana habitat in Meru Betiri National Park. *IOP Conference Series: Earth and Environmental Science*, *394*(1). https://doi.org/10.1088/1755-1315/394/1/012010

McGregor, G. R., & Nieuwolt, S. (1998). *Tropical Climatology: An Introduction to the Climates of the Low Latitudes* (2nd Editio). Wiley.

Meili, N., Acero, J. A., Peleg, N., Manoli, G., Burlando, P., & Fatichi, S. (2021). Vegetation cover and plant-trait effects on outdoor thermal comfort in a tropical city. *Building and Environment*, *195*(February), 107733. https://doi.org/10.1016/j.buildenv.2021.107733

Morakinyo, T. E., Lau, K. K. L., Ren, C., & Ng, E. (2018). Performance of Hong Kong's common trees species for outdoor temperature regulation, thermal comfort and energy saving. *Building and Environment*, *137*, 157–170. https://doi.org/10.1016/j.buildenv.2018.04.012

Mulyadi, A. M. (2020). Tingkat pelayanan fasilitas pejalan kaki di kawasan transit oriented development Dukuh Atas Jakarta. *Jurnal HPJI (Himpunan Pengembangan Jalan Indonesia)*, *6*(2), 139–150. https://doi.org/10.26593/jh.v6i2.4057.139-150

Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening*, *4*(3–4), 115–123. https://doi.org/10.1016/j.ufug.2006.01.007

Oduor, A. M. O., Leimu, R., & van Kleunen, M. (2016). Invasive plant species are locally adapted just as frequently and at least as strongly as native plant species. *Journal of Ecology*, *104*(4), 957–968. https://doi.org/10.1111/1365-2745.12578

Perini, K., Chokhachian, A., & Auer, T. (2018). Green streets to enhance outdoor comfort. In *Nature Based Strategies for Urban and Building Sustainability*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-812150-4.00011-2

Picot, X. (2004). Thermal comfort in urban spaces: Impact of vegetation growth. Case study: Piazza della Scienza, Milan, Italy. *Energy and Buildings*, *36*(4), 329–334. https://doi.org/10.1016/j.enbuild.2004.01.044

Putri, N. A., Hermawan, R., & Karlinasari, L. (2021). Measuring thermal comfort in a built environment: A case study in a central business district, Jakarta. *IOP Conference Series: Earth and Environmental Science*, *918*(1). https://doi.org/10.1088/1755-1315/918/1/012024

Qin, X., Fang, M., Yang, D., & Wangari, V. W. (2023). Quantitative evaluation of attraction intensity of highway landscape visual elements based on dynamic perception. *Environmental Impact Assessment Review*, *100*, 107081. https://doi.org/10.1016/j.eiar.2023.107081

Richards, D. R., Fung, T. K., Belcher, R. N., & Edwards, P. J. (2020). Differential air temperature cooling performance of urban vegetation types in the tropics. *Urban Forestry and Urban Greening*, *50*(March). https://doi.org/10.1016/j.ufug.2020.126651

Rusdayanti, N., Karuniasa, M., & Nasrullah, N. (2021). Thermal comfort assessment over the past two decades in different landscape areas within Palembang City. *IOP Conference Series: Earth and Environmental Science*, *724*(1). https://doi.org/10.1088/1755-

1315/724/1/012010

Samsoedin, I., & Waryono, T. (2010). *Hutan Kota dan Keanekaragaman Jenis Pohon di Jabodetabek*. Yayasan KEHATI - Indonesia Biodiversity Foundation.

Sharmin, M., Tjoelker, M. G., Pfautsch, S., Esperón-Rodriguez, M., Rymer, P. D., & Power, S. A. (2023). Tree traits and microclimatic conditions determine cooling benefits of urban trees. *Atmosphere*, *14*(3). https://doi.org/10.3390/atmos14030606

Simangunsong, N. I., & Fitri, R. (2021). Identification of oxygen production and oxygen demands in parks and green paths as an environmental sustainability effort in Selong area, Jakarta, Indonesia. *Ecology, Environment and Conservation*, *27*(1), 146–151.

Simangunsong, N. I., Fitri, R., & Besila, Q. A. (2021). Vegetation composition on ecological function in Mataram Merah Park, Jakarta. *BIOLINK (Jurnal Biologi Lingkungan Industri Kesehatan)*, *7*(2), 123–129. https://doi.org/10.31289/biolink.v7i2.3883

Spagenberg, J. (2004). *Improvement of Urban Climate in Tropical Metropolis – A case study in Maracanã/ Rio de Janeiro*. University of Applied Science, Cologne, Germany.

Stewart, R. H. (2008). Introduction to physical oceanography. In *Texas A&M University Library*. https://hdl.handle.net/1969.1/160216

Syalianda, S. I., & Kusumastuti, R. D. (2021). Implementation of smart city concept: A case of Jakarta Smart City, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *716*(1). https://doi.org/10.1088/1755-1315/716/1/012128

Wang, Y., & Akbari, H. (2016). The effects of street tree planting on urban heat island mitigation in Montreal. *Sustainable Cities and Society*, *27*, 122–128. https://doi.org/10.1016/j.scs.2016.04.013

Wu, J., Chen, B., Reynolds, G., Xie, J., Liang, S., O'Brien, M. J., & Hector, A. (2020). Monitoring tropical forest degradation and restoration with satellite remote sensing: A test using Sabah Biodiversity Experiment. In *Advances in Ecological Research* (1st ed., Vol. 62). Elsevier Ltd. https://doi.org/10.1016/bs.aecr.2020.01.005

Wulanningrum, S. D. (2021). Kajian kenyamanan jalur pejalan kaki di Jalan Taman Mini 1 dan Jalan Raya Pondok Gede, Jakarta Timur. *Jurnal Muara Sains, Teknologi, Kedokteran Dan Ilmu Kesehatan*, *5*(1), 155. https://doi.org/10.24912/jmstkik.v5i1.9391

Yang, Y., Zhou, D., Gao, W., Zhang, Z., Chen, W., & Peng, W. (2018). Simulation on the impacts of the street tree pattern on built summer thermal comfort in cold region of China. *Sustainable Cities and Society*, *37*, 563–580. https://doi.org/10.1016/j.scs.2017.09.033

Zeng, F., Simeja, D., Ren, X., Chen, Z., & Zhao, H. (2022). Influence of urban road green belts on pedestrian-level wind in height-asymmetric street canyons. *Atmosphere*, *13*(8). https://doi.org/10.3390/atmos13081285

Zhang, L., Zhan, Q., & Lan, Y. (2018). Effects of the tree distribution and species on outdoor environment conditions in a hot summer and cold winter zone: A case study in Wuhan residential quarters. *Building and Environment*, *130*(September 2017), 27–39. https://doi.org/10.1016/j.buildenv.2017.12.014