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Research Original Article

Analysis of Thermal Comfort in Green Open Spaces (GOS) Using the Temperature Humidity Index (THI) Approach

(Case Study: City Park Green Open Space in Lhokseumawe)

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Abstract
The city of Lhokseumawe, located in a coastal area with a tropical monsoon climate, faces challenges in creating comfort due to high solar radiation and air temperatures. The Green Open Spaces (GOS) in this city, such as Riyadhah Park, Hiraq Field, and General Sudirman Field, are often utilized for various activities like walking, recreation, sports, eating, drinking, commercial activities, ceremonies, and playing. Public comfort, particularly in city parks, should be prioritized to create an ideal environment. This study aims to analyze thermal comfort using the Temperature Humidity Index (THI) approach. The research was conducted from May 27 to June 10, 2024, during a period when temperatures in Indonesia increased due to the apparent movement of the sun. The method used is quantitative descriptive research. Based on measurements taken over 15 days at three different intervals, the morning THI in the three study locations, namely Riyadhah Park, Hiraq Field, and General Sudirman Field, indicated that shaded areas with vegetation had slightly lower THI values compared to unshaded areas. The average THI for shaded areas ranged from 29,3°C to 29,7°C, while unshaded areas ranged from 29,7°C to 30°C. All areas in the morning were classified as moderately comfortable. At midday, the THI difference between shaded and unshaded areas was more pronounced. THI in shaded areas at Riyadhah Park, Hiraq Field, and General Sudirman Field ranged from 31,9°C to 32,2°C, while unshaded areas had higher values, between 32,4°C and 32,6°C. All areas at the three locations during midday fell into the uncomfortable category. Measurements taken in the afternoon showed a pattern similar to midday, where shaded areas had slightly lower THI values than unshaded areas. The average THI for shaded areas ranged from 30,7°C to 30,9°C, while unshaded areas ranged from 31,1°C to 31,3°C. All areas at the three locations in the afternoon were classified as uncomfortable. Overall, shaded areas in the three study locations consistently showed lower THI values compared to unshaded areas, indicating that the presence of vegetation can help reduce temperatures and enhance thermal comfort, especially during times of higher heat intensity, such as midday and afternoon.
Keywords: Green Open Space (GOS), Thermal Comfort, Temperature Humidity Index (THI)

Introduction
Green Open Space (GOS) is an open area planted with various types of vegetation. This area plays a crucial ecological role, especially as an oxygen producer. (Mannan, 2018), ecological area of flora and fauna (Bryantara et al., 2019), as well as a space for activities and social interactions among the residents of an area (Santi et al., 2019). For urban areas, the presence of green open spaces is crucial. Green open spaces provide various benefits to the climate, including heat retention, noise reduction, and decreased air pollution levels. Additionally, green open spaces serve as microclimate regulators that can lower surface temperatures. This directly impacts air temperature circulation and can affect an individual's quality of life. (Ahmad et al., 2012)Thus, the presence of green open spaces in a city becomes very important and significant, considering that they contribute to creating a pleasant environment for its inhabitants.

Urban park green open spaces should have two main aspects: aesthetics and comfort. In terms of comfort, urban park green open spaces are expected to help develop the microclimate within metropolitan areas, allowing the community to feel happy and comfortable engaging in activities both inside and around these green spaces (Zahra et al., 2012).

Various internal and external factors, including air temperature, humidity, light intensity, and noise, as well as surrounding environmental conditions that can disturb individuals either directly or indirectly, can contribute to discomfort in relation to green open spaces. (Sugiasih, 2013).

The human response to temperature stimuli from the surrounding environment is known as thermal comfort (Yudha et al., 2023). The reactions exhibited by individuals include feelings of warmth or chill. The concept of thermal comfort is always associated with the microclimate, which consists of climatic factors such as air temperature, humidity, and wind speed (Saroinsong et al., 2017).

The existence of Lhokseumawe City in a coastal area with a tropical monsoon climate, characterized by strong solar radiation and high air temperatures, presents a challenge for creating comfort. To assess thermal comfort in green open spaces in Lhokseumawe City, a study was conducted using the Temperature Humidity Index (THI) approach. Based on the above description, the research problem examined is how the thermal comfort conditions are in each green open space of Lhokseumawe City according to standards through the Temperature Humidity Index (THI) approac.

Literature Review

Thermal comfort is a measure that involves a complex interaction between physical aspects such as air temperature, humidity, and air movement, along with individuals' physiological and psychological responses to the thermal environment they experience. According to Szokolay, thermal comfort is a state in which individuals feel satisfied with the thermal environment they are experiencing (Szokolay, 1973).

The comfort of an area is greatly influenced by the local microclimate, as climate factors directly affect human activities and metabolism. However, we cannot use all climatic parameters directly to determine the comfort level of a region (Lakitan, 2002). Air temperature and humidity are climatic parameters that are frequently used in studying air comfort issues (Gates, 1972).

Lippsmeier proposed several factors that determine thermal comfort in an environment, which include (Lippsmeier, 1994):

a. Shading systems,
b. Temperature,
c. Humidity.

Thermal comfort is studied by experts, one of whom works quantitatively using the Temperature Humidity Index (THI) method. THI is an index that was empirically formulated by Nieuwolt (1977) which determines the effect of heat conditions on human well-being through the combination of temperature and humidity (Effendy et al., 2006).

The THI method focuses on the aspects of air temperature and relative humidity without considering the relationship with human habits related to diet, clothing, and other factors (Emmanuel, 2005). However, the THI method is often used in tropical areas in general, particularly in outdoor spaces. The THI method has been widely applied in tropical regions, including Southeast Asian countries such as Indonesia and Malaysia (Marsitha et al., 2019).

The classification of Temperature Humidity Index (THI) values in the tropical climate of Indonesia can be reviewed in the following table:

Table 1. THI Value Classification (Sugiasih, 2013)

Comfort Level	THI Value (°C)
Comfortable	<29
Moderately Comfortable	29 – 30,5
Uncomfortable	>30,5

This comfort level value is calculated using a specific formula (Nieuwolt, 1977).

$$THI = 0{,}8 \times T + ((RH \times T)/500)$$

Where:

THI : Temperature Humidity Index (°C)
T : Temperature (°C)
RH : Relative Humidity (%)

The analysis results using the THI method indicate a standard index that serves to determine the impact and comfort experienced by humans based on air temperature (°C) and relative humidity (%).

Materials & Methods

This research uses a quantitative descriptive method. Quantitative descriptive research is a type of study used to analyze data by describing the collected data as it is, without further manipulation or interpretation. The research location is in Banda Sakti District, Lhokseumawe City. Data collection was conducted over 15 days, from May 27, 2024, to June 10, 2024. The population in this study is the Green Open Spaces (GOS) city parks located in Banda Sakti District, Lhokseumawe City, while the research samples consist of three sites Riyadhah Park, Hiraq Field, and Sudirman Field.

Picture 1. Distribution Points of Research Samples, Analysis (2024)

(a)

(b)

(c)

Picture 2. Research Samples: (a) Riyadhah Park, (b) Hiraq Field, (c) Sudirman Field, Google Earth Pro (2024)

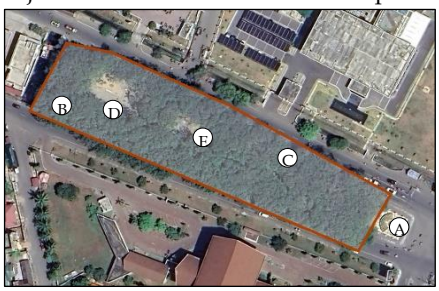
The object of this research is the air temperature and humidity data from the three research samples. This study was conducted using primary data obtained from observations, field surveys, and measurements of temperature and humidity using a digital measuring instrument known as an environment meter.

Temperature and humidity data were obtained at several measurement points based on specific criteria. The evaluation criteria are as follows:

1. Points with paved surfaces,
2. Points with grass surfaces,
3. Points with dense planting spacing,
4. Points with sparse planting spacing,
5. Points without tree shade.

These points are further divided into two zones: those with vegetation shade and those without vegetation shade. This division aims to determine the influence of vegetation as a regulator of air temperature and humidity.

The following are the measurement points and the evaluation criteria for each measurement point of the research objects from the three research samples.



(a)

(b)

(c)

Picture 3. Measurement Points for Temperature and Humidity: (a) Riyadhah Park, (b) Hiraq Field, (c) Sudirman Field, Analysis (2024)

Table 2. Evaluation Criteria for Each Measurement Point, Analysis (2024)

Riyadhah Park		Hiraq Field		Sudirman Field	
Points	**Criteria**	**Points**	**Criteria**	**Points**	**Criteria**
A	Points without tree shade (TN)	A	Points with paved surfaces (TN)	A	Points with paved surfaces (TN)
B	Points with grass surfaces (DN)	B	Points without tree shade (TN)	B	Points with grass surfaces (TN)
C	Points with dense planting spacing (DN)	C	Points with dense planting spacing (DN)	C	Points without tree shade (TN)
D	Points with sparse planting spacing (DN)	D	Points with sparse planting spacing (DN)	D	Points with dense planting spacing (DN)
E	Points with paved surfaces (DN)	E	Points with grass surfaces (DN)	E	Points with sparse planting spacing (DN)

Note: TN: Without shade, DN: With shade

Temperature and humidity measurements were conducted directly three times a day at each designated point in the research samples. The following are the measurement times for three different intervals at each research sample.

Table 3. Daily Temperature and Humidity Measurement Times, Analysis (2024)

Sample	Time (WIB)		
	Morning	Afternoon	Evening
Sudirman Field	07.00 – 07.25	12.00 – 12.25	16.30 – 16.55
Hiraq Field	07.35 – 08.00	12.35 – 13.00	17.05 – 17.30
Riyadhah Park	08.05 – 08.30	13.05 – 13.30	17.35 – 18.00

There are two variables in this study: the factors that determine thermal comfort (temperature and humidity) theory Lippsmeier (1994) and the thermal comfort index value based on the Temperature Humidity Index (THI) theory Nieuwolt (1977).

Results And Discussion

Analysis of Thermal Comfort Based on THI

This template is designed to assist you in preparing your manuscript; it is an exact representation of the format The measurement of thermal comfort index in this study uses two climatic parameters, namely temperature and humidity, based on the formula from Nieuwolt (1977), in three green open spaces in Lhokseumawe City that are part of the research samples. The following presents the results of the thermal comfort index calculations based on the THI.

1. Riyadhah Park

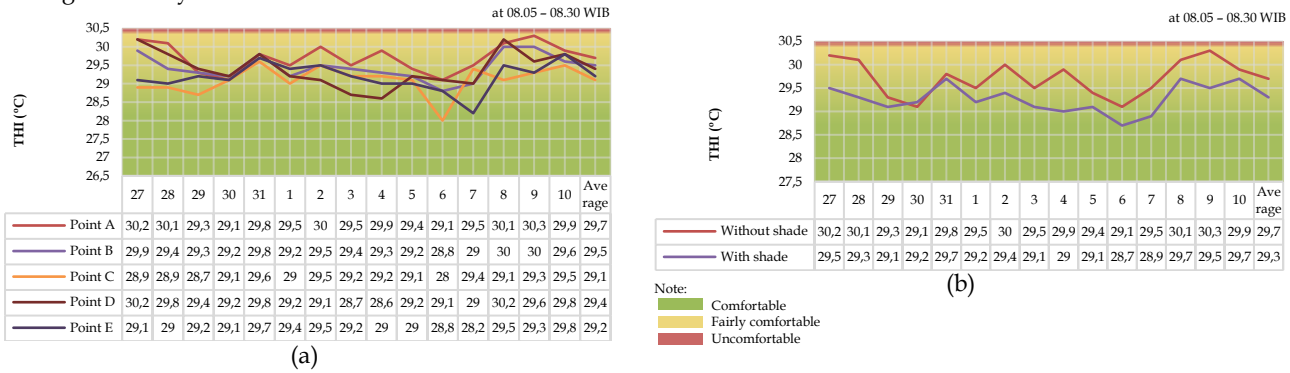
The following presents the results of air temperature and humidity measurements taken in the morning from 08:05 - 08:30 WIB at Riyadhah Park.

Table 4. Results of Temperature and Humidity Measurements Riyadhah Park at 08.05 – 08.30 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN	DN				TN	DN			
	A	B	C	D	E	A	B	C	D	E
27 May 2024	31,5	31,2	30,0	31,5	30,3	80,0	79,9	81,5	79,3	80,5
28 May 2024	31,5	30,6	30,0	31,2	30,2	78,2	80,6	81,7	77,5	79,9
29 May 2024	30,5	30,5	29,7	30,6	30,3	80,2	80,6	82,7	80,3	81,5
30 May 2024	30,5	30,4	30,2	30,4	30,3	77,6	80,6	81,0	80,8	80,2
31 May 2024	31,2	30,8	31,0	31,2	31,1	77,4	83,2	77,9	77,5	78,0
01 June 2024	30,8	30,4	30,1	30,4	30,5	78,6	80,4	81,5	80,0	81,3
02 June 2024	31,3	30,7	30,7	30,2	30,7	79,6	80,4	80,7	81,8	80,5
03 June 2024	30,7	30,5	30,3	29,8	30,3	79,8	82,0	82,1	81,3	81,5
04 June 2024	31,2	30,5	30,4	29,8	30,1	79,7	80,6	81,0	80,1	81,2
05 June 2024	30,6	30,3	30,2	30,4	30,2	80,1	81,2	81,7	80,4	80,5
06 June 2024	30,2	29,9	29,0	30,2	29,9	81,5	82,2	82,7	81,2	81,6
07 June 2024	30,8	30,2	30,5	30,2	29,3	79,7	80,5	81,7	80,1	80,5
08 June 2024	31,4	31,2	30,2	31,5	30,7	79,2	80,7	81,4	79,8	80,4
09 June 2024	31,8	31,3	30,5	31,0	30,5	77,1	79,3	80,0	77,4	79,8
10 June 2024	31,4	31,0	30,8	31,2	31,0	75,8	78,2	79,3	77,9	80,0
Average	31,0	30,6	30,2	30,6	30,4	79,0	80,7	81,1	79,7	80,5

Note: TN: Without shade, DN: With shade

Here is presented a graph showing the calculated THI values at Riyadhah Park in the morning at 08.05 – 08.30 WIB during the 15 days of measurement.



Graph 1. (a) Value of THI Riyadhah Park at 08.05 – 08.30 WIB, (b) Difference in THI Values Riyadhah Park at 08.05 – 08.30 WIB, Analysis (2024)

The graph above shows that the THI values during the morning measurement from 08.05 – 08.30 WIB all measurement points fall into the fairly comfortable category. The lowest THI value was recorded at Point C (the area with closely spaced planting) with an average of only 29,1°C. The second lowest THI value was at Point E (the area with a hard surface) with an average of 29,2°C, differing by only 0,1°C from Point C. The third lowest THI value was recorded at Point D (the area

with widely spaced planting) with an average of 29,4°C. The highest THI value was noted at Point A (the area without vegetation cover) with an average of 29,7°C, followed closely by Point B (the area with grass cover).

There is a noticeable difference in THI values during the morning measurements at Riyadhah Park between the zones with and without vegetation cover, where the THI in the vegetated zone is lower, with an average of 29,3°C, compared to the non-vegetated zone at 29,8°C. The difference in THI values between these two points is 0,5°C. The overall average THI value calculated from all measurement points is 29,4°C, which falls into the fairly comfortable category.

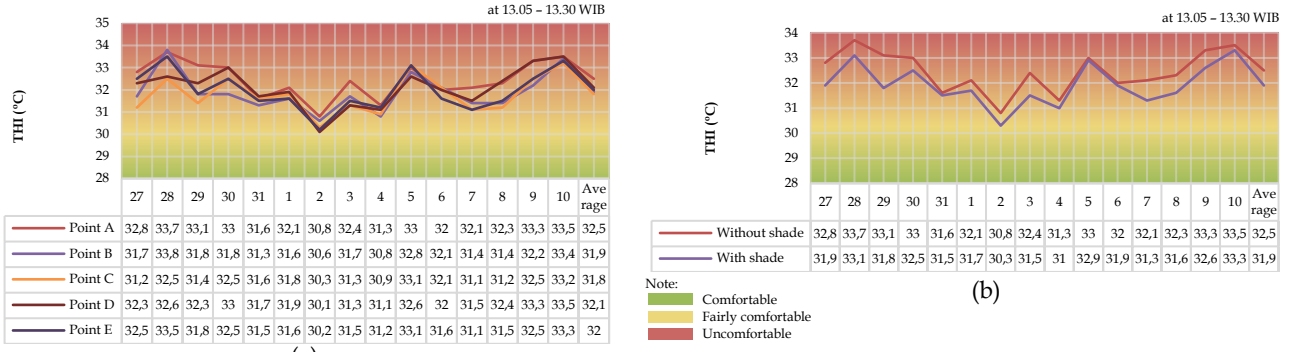
Here are the results of the air temperature and humidity measurements taken during the day at 13.05 – 13.30 WIB at Riyadhah Park.

Table 5. Results of Temperature and Humidity Measurements Riyadhah Park at 13.05 – 13.30 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN	DN				TN	DN			
	A	B	C	D	E	A	B	C	D	E
27 May 2024	36,3	35,2	34,2	36,1	35,7	51,3	50,5	55,7	47,7	55,2
28 May 2024	37,1	36,9	35,4	36,0	36,6	54,2	57,7	58,8	52,1	57,3
29 May 2024	36,3	34,5	34,1	35,1	34,7	55,9	60,2	60,5	60,4	57,5
30 May 2024	36,2	35,2	35,5	36,0	35,6	56,4	52,4	58,1	58,8	57,1
31 May 2024	34,5	34,3	34,1	34,4	34,5	58,3	56,4	63,6	61,3	57,0
01 June 2024	35,2	34,5	34,8	34,8	34,5	56,3	58,5	56,9	58,3	58,1
02 June 2024	33,5	33,2	32,7	32,5	32,8	60,0	60,5	62,9	63,3	60,1
03 June 2024	35,8	34,6	34,0	34,5	34,4	52,5	58,4	60,3	54,3	58,5
04 June 2024	36,1	35,5	35,5	35,9	36,0	33,6	34,2	35,8	33,7	33,4
05 June 2024	37,3	36,8	36,8	36,6	36,9	42,5	45,9	50,4	46,0	48,2
06 June 2024	34,9	34,8	34,8	34,9	34,8	58,6	60,5	61,8	58,3	54,1
07 June 2024	35,1	34,2	33,6	34,3	33,8	57,8	59,3	62,7	58,6	60,7
08 June 2024	36,0	34,9	34,3	35,8	34,5	48,2	49,3	55,2	52,1	56,5
09 June 2024	37,5	36,2	36,3	37,2	36,3	43,6	44,5	47,5	47,2	47,2
10 June 2024	37,8	37,6	37,2	37,6	37,5	43,2	44,5	45,6	45,2	44,5
Average	36,0	35,2	34,9	35,4	35,2	51,5	52,9	55,7	53,2	53,7

Note: TN: Without shade, DN: With shade

The graph below illustrates the results of the THI value calculations at Riyadhah Park during the afternoon at 13.05 – 13.30 WIB during the 15 days of measurement.



Graph 2. (a) Value of THI Riyadhah Park at 13.05 – 13.30 WIB, (b) Difference in THI Values Riyadhah Park at 13.05 – 13.30 WIB, Analysis (2024)

The graph above shows that the THI values at all measurement points in Riyadhah Park afternoon at 1305 – 13.30 WIB fall into the uncomfortable category. The measurement point with the highest average THI value is point A (the area without vegetation cover), with a value of 32,5°C. The lowest average THI value is found at point C (the area with closely planted vegetation), which has an average of 31,8°C. The next lowest point is point B (the area with grass cover), with an average THI value of 31,9°C, only 0,1°C higher than point C. There is a noticeable difference in THI values during the afternoon measurements at Taman Riyadhah, where the THI in areas with vegetation cover is lower, averaging 31,9°C, compared to 32,5°C in areas without vegetation cover. Both zones fall into the uncomfortable category, with a difference of 0,5°C between them.

Here are the results of the air temperature and humidity measurements taken in the afternoon from 17.35 – 18.300 WIB at Riyadhah Park.

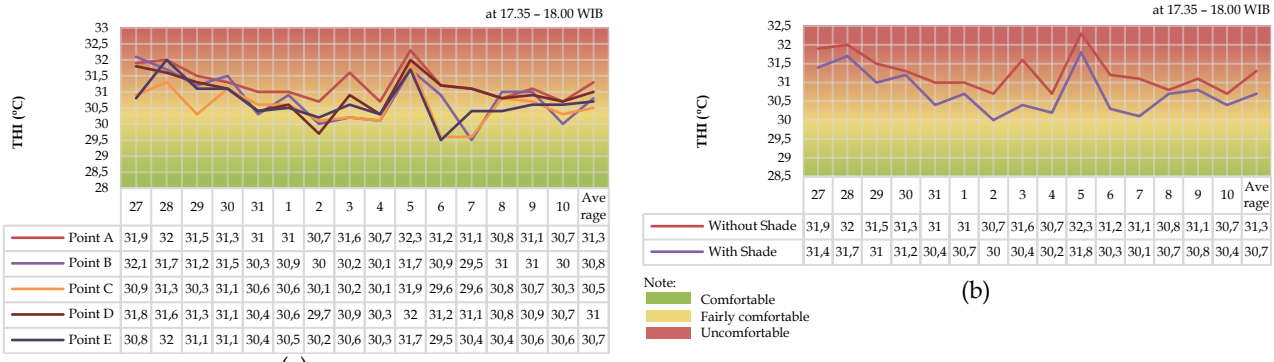
Table 6. Results of Temperature and Humidity Measurements Riyadhah Park at 17.35 – 18.00 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN	DN				TN	DN			
	A	B	C	D	E	A	B	C	D	E
27 May 2024	34,6	34,5	33,0	34,5	33,2	61,3	65,3	68,0	60,2	64,2
28 May 2024	34,7	34,1	33,6	34,2	34,7	60,9	65,2	65,8	62,5	60,7
29 May 2024	33,9	33,5	32,5	33,6	33,3	64,2	65,8	65,9	65,7	66,7
30 May 2024	33,7	33,6	33,1	33,5	33,4	64,6	68,6	70,2	64,1	66,2
31 May 2024	33,1	32,3	32,4	32,6	32,4	67,6	69,1	71,8	66,5	69,2
01 June 2024	33,5	33,2	32,6	32,9	33,0	62,8	65,2	69,3	64,9	62,6

02 June 2024	32,7	31,9	31,9	31,5	32,1	69,7	70,5	72,3	71,2	70,9
03 June 2024	33,8	32,1	32,0	33,2	32,6	67,1	69,9	71,1	65,5	68,7
04 June 2024	33,7	33,1	33,0	33,2	33,3	55,2	55,2	56,4	55,8	55,4
05 June 2024	34,7	34,2	34,1	34,5	34,0	64,8	63,6	68,2	63,3	66,2
06 June 2024	33,5	32,9	31,6	33,5	31,6	65,8	69,5	68,9	65,9	66,8
07 June 2024	33,2	31,5	31,3	33,1	32,3	68,8	68,2	72,2	69,7	70,9
08 June 2024	33,0	33,1	32,8	33,0	32,6	66,2	69,0	69,3	66,0	65,5
09 June 2024	33,8	33,6	33,2	33,6	33,2	60,0	60,7	62,1	59,3	60,8
10 June 2024	32,8	32,0	32,2	32,8	32,6	68,3	69,2	69,8	68,7	69,5
Average	33,6	33,0	32,6	33,3	33,0	64,5	66,3	68,1	64,6	65,6

Note: TN: Without shade, DN: With shade

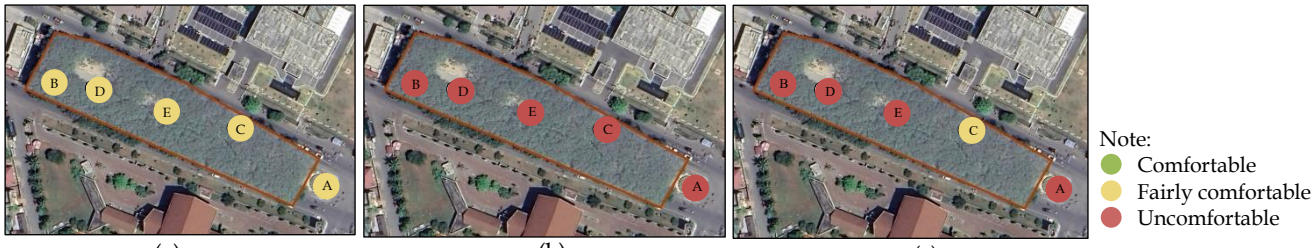
Below is the graph showing the results of the THI value calculations at Taman Riyadhah in the afternoon at 17.35 – 18.00 WIB during the 15 days of measurement.



Graph 3. (a) Value of THI Riyadhah Park at 17.35 – 18.00 WIB, (b) Difference in THI Values Riyadhah Park at 17.35 – 18.00 WIB, Analysis (2024)

The graph presented above shows that only the THI value at point C (the point with closely spaced plantings) falls within the comfortable category, with an average of 30,5°C. This point also represents the measurement with the lowest THI value in the afternoon at 17.35 – 18.00 WIB at Riyadhah Park. Furthermore, the highest average THI value is at point A (the point without vegetation cover), recorded at 31,3°C. Points A, B, D, and E fall into the uncomfortable category, as their average THI values exceed 30,5°C. There is a difference in THI values during the afternoon measurements at Taman Riyadhah, where the THI in the zone with vegetation cover is lower, averaging 30,7°C, compared to 31,3°C in the zone without vegetation cover. Both zones are classified as uncomfortable, with a difference of 0,5°C between the two points.

Here is a presentation of the THI value category at each measurement point in Riyadhah Park in the morning 08.05 – 08.30 WIB, afternoon at 13.05 – 13.30 WIB, and evening at 17.35 – 18.00 WIB.



(a) (b) (c)

Picture 4. Category of THI Values at Riyadhah Park (a) Morning at 08.05 – 08.30 WIB, (b) Afternoon at 13.05 – 13.30 WIB, (c) Evening at 17.35 – 18.00 WIB, Analysis (2024)

2. Hiraq Field

Here are the results of the air temperature and humidity measurements taken in the morning at 07.35 – 08.00 WIB at Hiraq Field.

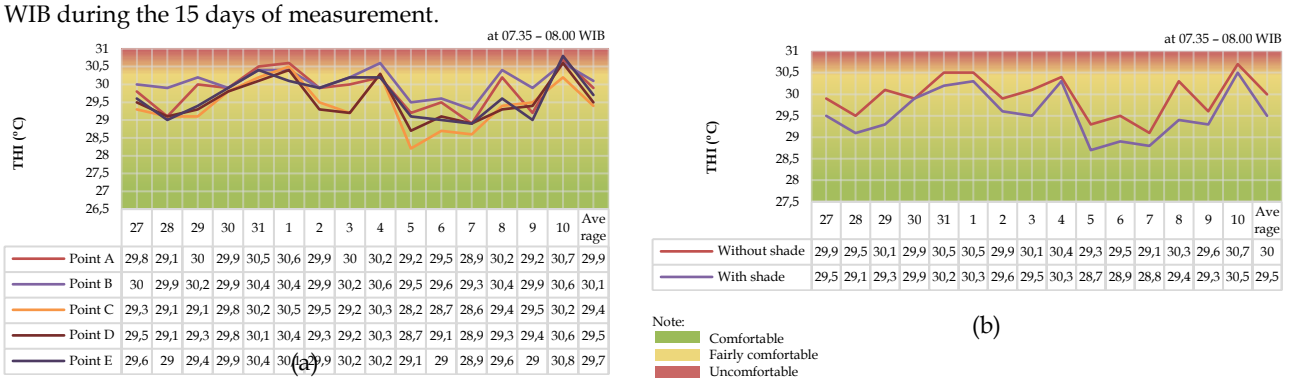
Table 7. Results of Temperature and Humidity Measurements Hiraq Field at 07.35 – 08.00 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN			DN		TN			DN	
	A	B	C	D	E	A	B	C	D	E
27 May 2024	31,2	31,3	30,5	30,8	30,8	77,8	78,9	80,5	79,3	80,1
28 May 2024	30,5	31,2	30,2	30,3	30,2	77,6	79,2	81,9	80,4	80,1
29 May 2024	31,2	31,4	30,2	30,5	30,5	80,9	81,3	82,3	80,3	82,1
30 May 2024	31,3	31,2	30,9	31,1	31,0	78,2	79,2	82,7	79,7	82,9
31 May 2024	32,0	31,9	31,5	31,5	31,8	76,6	76,9	79,6	77,2	78,5
01 June 2024	31,9	31,7	31,7	31,6	31,3	79,9	79,9	80,5	80,7	80,3
02 June 2024	31,1	31,0	30,6	30,4	31,1	81,2	82,0	82,2	81,5	81,3
03 June 2024	31,2	31,5	30,2	30,2	31,3	80,3	79,5	82,9	82,7	82,3
04 June 2024	31,5	31,9	31,4	31,6	31,5	79,1	79,2	81,7	79,8	80,0
05 June 2024	30,4	30,7	29,2	29,8	30,2	80,0	79,8	83,4	81,3	82,6

06 June 2024	30,6	30,8	29,8	30,1	30,0	81,5	80,1	82,3	82,9	82,6
07 June 2024	30,1	30,5	29,6	30,0	30,1	80,5	79,7	82,5	81,6	80,5
08 June 2024	31,5	31,7	30,5	30,5	30,9	79,8	79,8	81,5	81,1	78,8
09 June 2024	30,8	31,1	30,7	30,5	30,1	74,2	80,6	80,9	81,3	80,9
10 June 2024	32,2	32,1	31,5	31,8	32,0	76,4	77,3	79,7	81,2	80,5
Average	31,2	31,3	30,6	30,7	30,9	78,9	79,6	81,6	80,7	80,9

Note: TN: Without shade, DN: With shade

Below is the graph showing the results of the THI value calculations at Hiraq Field in the morning at 07.35 – 08.00 WIB during the 15 days of measurement.



(a)

Graph 4. (a) Value of THI Hiraq Field at 07.35 – 08.00 WIB, (b) Difference in THI Values Hiraq Field at 07.35 – 08.00 WIB, Analysis (2024)

It can be seen in the graph presented above that the results of the THI value calculations for the morning at 07.35 – 08.00 WIB at Hiraq Field. The average THI value from all measurement points falls into the category of moderately comfortable. The lowest average THI value is found at point C (the point with closely spaced planting) at 29,4°C. The highest average THI value is at point B (the point with grass cover) at 30,1°C. The THI value for the zone with vegetation cover is lower, with an average of 29,5°C, while the zone without vegetation cover is 30°C, both zones are classified as comfortable. The difference in THI values between the two points is 0,4°C.

Here are the results of air temperature and humidity measurements during the day from 12.35 – 13.00 WIB at Hiraq Field.

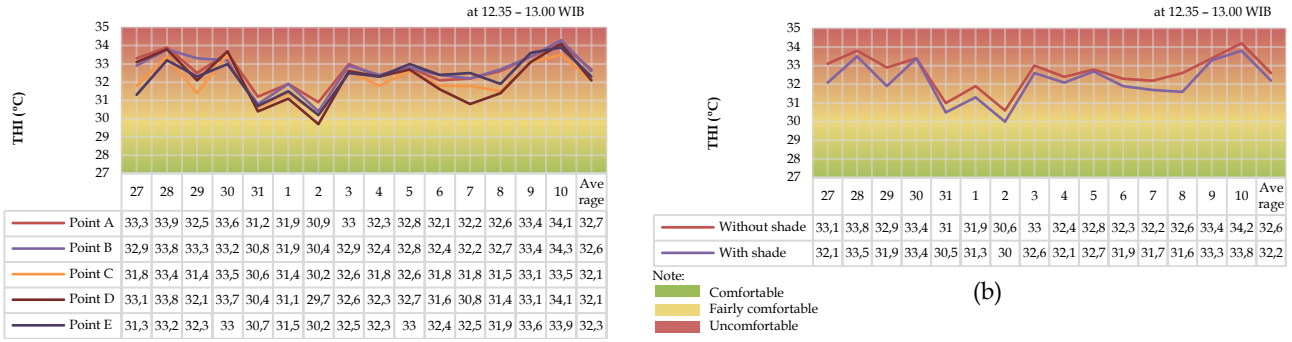
Table 8. Results of Temperature and Humidity Measurements Hiraq Field at 12.35 – 13.00 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN			DN		TN			DN	
	A	B	C	D	E	A	B	C	D	E
27 May 2024	36,9	37,1	35,0	36,7	35,2	51,2	43,9	53,7	50,3	45,2
28 May 2024	37,5	37,5	36,7	37,2	36,9	51,4	50,3	55,3	54,2	50,5
29 May 2024	36,3	36,9	34,8	35,7	35,9	48,2	50,8	51,6	49,5	50,0
30 May 2024	37,1	36,8	36,4	36,8	36,6	52,3	51,7	59,8	58,3	51,2
31 May 2024	34,3	33,7	33,5	33,2	33,5	55,4	56,3	56,5	57,3	57,5
01 June 2024	35,2	35,0	34,4	34,1	34,6	53,5	55,6	56,6	55,3	55,6
02 June 2024	33,6	32,9	32,7	32,1	32,7	60,3	61,5	61,7	62,3	62,5
03 June 2024	36,5	36,4	35,5	35,6	35,9	52,6	51,9	59,1	57,3	52,9
04 June 2024	37,2	37,1	36,5	36,8	37,0	34,5	37,1	36,2	38,4	36,7
05 June 2024	37,8	37,9	37,2	37,2	37,5	33,8	32,3	37,5	39,2	40,2
06 June 2024	35,6	35,5	34,6	34,8	35,4	50,6	56,8	59,8	53,7	57,8
07 June 2024	35,2	35,3	34,4	33,5	35,2	56,7	55,6	62,8	59,6	62,3
08 June 2024	36,2	36,5	34,8	34,8	34,9	49,7	48,3	52,5	50,9	56,9
09 June 2024	37,7	37,8	37,0	37,2	37,6	43,5	42,2	47,5	44,6	46,8
10 June 2024	38,4	38,2	37,4	37,6	37,8	44,2	48,6	47,6	53,9	48,2
Average	36,4	36,3	35,4	35,6	35,8	49,2	49,5	53,2	52,3	51,6

Note: TN: Without shade, DN: With shade

Below is the graph showing the results of the THI value calculations at Hiraq Field in the day at 12.35 – 13.00 WIB during the 15 days of measurement.

The graph above shows that the average THI value during daytime measurements at 12.35 – 13.00 WIB all measurement points fall into the uncomfortable category, exceeding 30,5°C. The lowest average THI value is found at point C (the point with dense planting) and point D (the point with sparse planting), both measuring 32,1°C. The highest average THI value is recorded at point A (the point with paved surfaces) with a value of 32,7°C. The THI value in the area with vegetation cover is lower, averaging 32,2°C, compared to 32,6°C in the area without vegetation cover, both zones fall into the uncomfortable category. The difference in THI values between these two zones is 0,4°C.



Graph 5. (a) Value of THI Hiraq Field at 12.35 – 13.00 WIB, (b) Difference in THI Values Hiraq Field at 12.35 – 13.00 WIB, Analysis (2024)

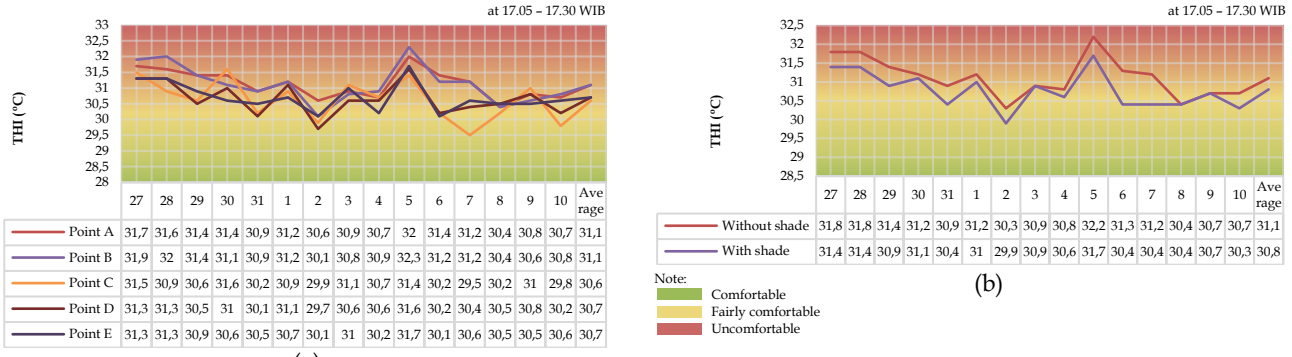
Here is the measurement result of air temperature and humidity in the afternoon from 17.05 – 17.30 WIB at Hiraq Field.

Table 9. Results of Temperature and Humidity Measurements Hiraq Field at 17.05 – 17.30 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN			DN		TN			DN	
	A	B	C	D	E	A	B	C	D	E
27 May 2024	34,1	34,5	33,7	33,8	33,9	65,2	62,2	66,9	63,2	62,3
28 May 2024	34,0	34,5	33,0	33,5	33,9	64,2	63,9	67,8	67,0	62,1
29 May 2024	33,8	33,9	32,7	32,7	33,2	64,8	63,2	68,5	66,8	65,2
30 May 2024	33,8	33,6	33,8	33,2	33,0	64,3	62,7	67,2	66,4	64,2
31 May 2024	33,2	33,1	32,2	32,2	32,8	64,7	67,5	68,2	67,9	64,8
01 June 2024	33,6	33,5	33,0	33,3	32,9	64,0	65,6	67,7	67,4	66,4
02 June 2024	32,6	32,0	31,7	31,5	31,9	68,8	70,7	71,7	70,8	71,3
03 June 2024	33,2	33,2	33,1	32,8	33,1	65,7	64,5	69,9	67,1	68,8
04 June 2024	33,7	33,9	33,4	33,4	33,3	55,7	56,4	59,7	58,7	53,5
05 June 2024	34,4	34,6	33,5	33,7	34,0	65,7	66,5	69,2	68,4	65,9
06 June 2024	33,7	33,4	32,2	32,2	32,3	66,5	66,9	68,5	68,2	65,3
07 June 2024	33,2	33,2	31,2	32,2	32,5	70,1	70,6	72,9	71,4	70,7
08 June 2024	32,5	32,6	32,2	32,5	32,6	67,8	65,7	68,9	68,8	68,4
09 June 2024	33,5	33,2	33,5	33,4	33,1	59,6	60,3	62,2	60,5	60,7
10 June 2024	33,9	34,0	32,7	33,2	33,8	52,5	52,7	55,2	55,1	53,0
Average	33,5	33,5	32,8	32,9	33,1	64,0	64,0	67,0	65,8	64,2

Note: TN: Without shade, DN: With shade

Below is the graph showing the results of the THI value calculations at Hiraq Field in the evening at 17.05 – 17.30 WIB during the 15 days of measurement.



Graph 6. (a) Value of THI Hiraq Field at 17.05 – 17.30 WIB, (b) Difference in THI Values Hiraq Field at 17.05 – 17.30 WIB, Analysis (2024)

The graph above shows the results of the THI value calculations at Hiraq Field in the evening at 17.05 – 17.30 WIB, it is known that all measurement points fall into the uncomfortable category. The points with the highest average THI values are point A (the point with a paved surface) and point B (the point without vegetation cover), both reaching 31,1°C. The lowest average THI value, which is nearly in the comfortable category, is at point C (the point with closely spaced planting), with a value of 30,6°C. The THI value in the zone with vegetation cover is lower, with an average of 30,8°C, while the zone without vegetation cover is at 31,1°C, both zones are in the uncomfortable category. The difference in THI values between these two points is 0,3°C.

Here is a presentation of the THI value category at each measurement point in Hiraq Field in the morning at 07.35 – 08.00 WIB, afternoon at 12.35 – 13.00 WIB, and evening at 17.05 – 17.30 WIB.

(a) (b) (c)

Picture 5. Category of THI Values at Hiraq Field (a) Morning at 07.35 – 08.30 WIB, (b) Afternoon at 12.35 – 13.00 WIB, (c) Evening at 17.05 – 17.30 WIB, Analysis (2024)

3. Sudirman Field

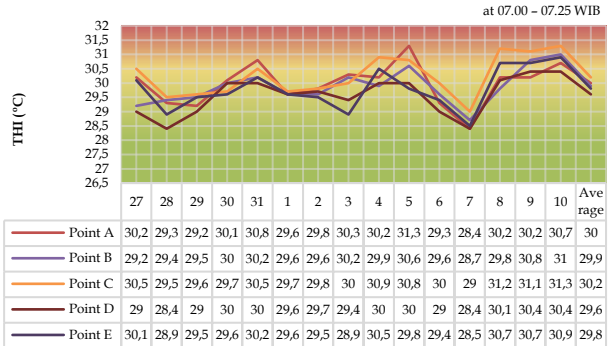
The table below shows the results of temperature and humidity measurements for the morning from 07.00 – 07.25 WIB at Sudirman Field.

Table 10. Results of Temperature and Humidity Measurements at Sudirman Field at 07.00 – 07.25 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN			DN		TN			DN	
	A	B	C	D	E	A	B	C	D	E
27 May 2024	31,8	30,5	32,1	30,2	31,5	75,2	79,3	75,3	79,5	77,3
28 May 2024	30,8	30,8	30,9	29,6	30,2	76,3	76,5	77,9	79,6	78,5
29 May 2024	30,6	30,7	31,0	30,2	30,7	76,9	80,8	77,7	80,5	80,4
30 May 2024	31,6	31,4	31,1	31,3	30,9	76,5	77,8	77,2	79,2	78,8
31 May 2024	32,6	31,9	32,2	31,5	31,8	72,7	73,2	73,1	76,1	75,3
01 June 2024	31,1	30,9	31,1	30,8	30,9	76,5	79,6	76,9	80,8	78,9
02 June 2024	31,4	31,0	31,3	31,2	30,7	75,1	76,8	75,7	75,9	80,2
03 June 2024	31,5	31,4	31,2	30,5	30,0	80,2	80,1	80,8	81,5	81,3
04 June 2024	31,7	31,2	32,3	31,2	31,8	76,9	78,7	78,0	81,4	79,1
05 June 2024	32,6	31,9	32,2	31,2	31,0	79,7	79,8	78,7	80,9	80,0
06 June 2024	30,6	30,8	31,2	30,1	30,5	79,5	80,1	81,5	81,8	81,9
07 June 2024	29,6	29,9	30,2	29,4	29,6	80,1	79,6	79,8	82,7	81,5
08 June 2024	31,6	31,2	32,5	31,3	31,9	77,5	77,9	80,2	80,5	81,2
09 June 2024	31,9	32,1	32,4	31,7	31,9	73,6	79,3	79,8	80,2	81,7
10 June 2024	32,4	32,5	32,7	31,7	32,0	74,2	76,2	79,1	80,1	82,7
Average	31,5	31,2	31,6	30,8	31,0	76,7	78,4	78,1	80,0	79,9

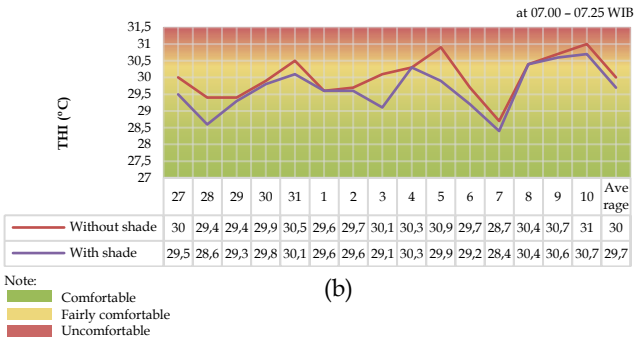
Note: TN: Without shade, DN: With shade

The graph below shows the results of the THI value calculation at Sudirman Field in the morning at 07.00– 07.25 WIB during the 15 days of measurement.



	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	Average
Point A	30,2	29,3	29,2	30,1	30,8	29,6	29,8	30,3	30,2	31,3	29,3	28,4	30,2	30,2	30,7	30
Point B	29,2	29,4	29,5	30	30,2	29,6	29,6	30,2	29,9	30,6	29,6	28,7	29,8	30,8	31	29,9
Point C	30,5	29,5	29,6	29,7	30,5	29,7	29,8	30	30,9	30,8	30	29	31,2	31,1	31,3	30,2
Point D	29	28,4	29	30	30	29,6	29,7	29,4	30	30	29	28,4	30,1	30,4	30,4	29,6
Point E	30,1	28,9	29,5	29,6	30,2	29,6	29,5	28,9	30,5	29,8	29,4	28,5	30,7	30,7	30,9	29,8

(a)



	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	Average
Without shade	30	29,4	29,4	29,9	30,5	29,6	29,7	30,1	30,3	30,9	29,7	28,7	30,4	30,7	31	30
With shade	29,5	28,6	29,3	29,8	30,1	29,6	29,6	29,1	30,3	29,9	29,2	28,4	30,4	30,6	30,7	29,7

(b)

Graph 7. (a) Value of THI Sudirman Field at 07.00 – 07.25 WIB, (b) Difference in THI Values Sudirman Field at 07.00 – 07.25 WIB, Analysis (2024)

The THI value calculation in the morning from 07.00- 07.25 WIB at Sudirman Field, as shown in the graph above, reveals that all measurement points fall within the quite comfortable category. Point C (without tree shade) has the highest average THI value at 30,2°C, while the lowest point is D (with close tree spacing) with an average of only 29,6°C. The THI value for the vegetated shade zone is lower, with an average of 29,7°C, compared to the non-vegetated shade zone at 30°C, both classified as quite comfortable. The THI difference between the two zones is 0,3°C.

Here are the results of the air temperature and humidity measurements taken during the day at 12.00 – 12.25 WIB at Sudirman Field.

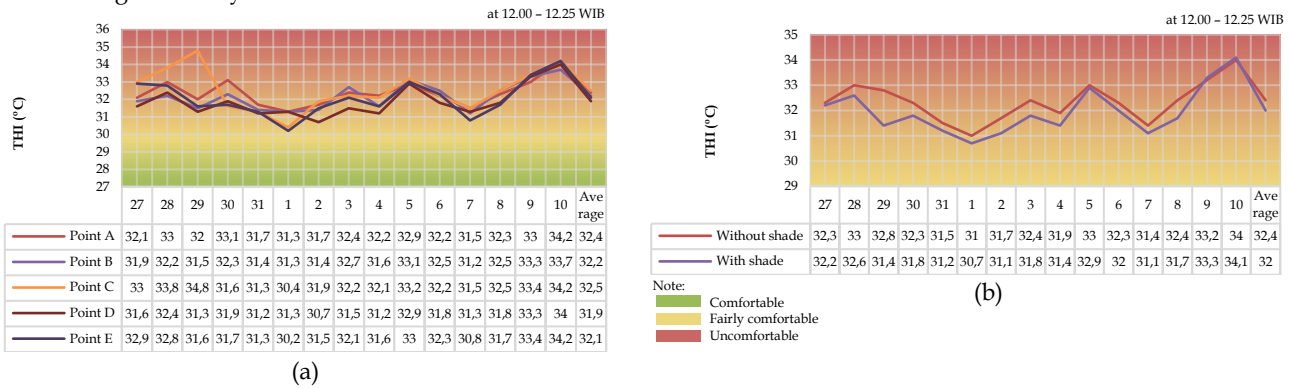
Table 11. Results of Temperature and Humidity Measurements at Sudirman Field at 12.00 – 12.25 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)		Humidity (%)	
	TN	DN	TN	DN

	A	B	C	D	E	A	B	C	D	E
27 May 2024	35,7	35,6	36,9	35,1	36,1	49,2	48,5	47,1	49,5	55,2
28 May 2024	37,1	36,2	38,1	36,2	36,9	44,2	45,4	43,1	46,9	44,3
29 May 2024	35,6	35,1	38,9	34,7	35,2	49,9	48,1	47,6	50,3	48,9
30 May 2024	36,3	35,4	35,2	35,0	34,8	56,3	55,6	48,7	56,0	55,3
31 May 2024	34,6	34,3	34,1	33,9	34,1	58,0	58,4	59,1	59,6	59,0
01 June 2024	34,4	34,5	33,8	34,5	32,8	54,3	53,8	50,1	53,3	59,9
02 June 2024	34,5	34,1	34,7	33,3	34,2	59,8	60,9	59,2	60,8	60,7
03 June 2024	35,6	35,8	35,8	34,6	35,2	55,6	56,3	49,8	55,9	56,3
04 June 2024	36,2	34,8	36,2	34,4	35,2	44,8	53,5	42,7	54,1	48,3
05 June 2024	37,0	37,1	36,9	36,8	36,8	44,3	45,9	49,5	46,6	47,9
06 June 2024	35,1	35,2	35,2	34,3	34,9	58,8	62,2	57,9	63,7	62,6
07 June 2024	34,7	33,9	35,1	33,8	34,2	54,5	60,3	49,3	62,6	50,8
08 June 2024	35,6	35,7	36,1	34,7	35,2	53,1	55,6	49,7	58,2	49,8
09 June 2024	36,7	36,6	37,0	36,4	36,6	49,6	55,2	51,7	56,8	56,8
10 June 2024	38,2	37,6	38,2	37,6	38,0	47,5	48,6	47,0	52,3	49,6
Average	35,8	35,5	36,1	35,0	35,3	52,0	53,9	50,2	55,1	53,7

Note: TN: Without shade, DN: With shade

Below is a graph of the results of the THI calculation at Jenderal Sudirman Field during the afternoon at 12.00– 12.25 WIB during the 15 days of measurement.



Graph 8. (a) Value of THI Sudirman Field at 12.00 – 12.25 WIB, (b) Difference in THI Values Sudirman Field at 12.00 – 12.25 WIB, Analysis (2024)

It can be seen from the graph displayed above that the average THI value during the afternoon at Sudirman Field, from 12:00 - 12:30 WIB, categorizes all measurement points as uncomfortable. The highest average THI value is found at Point C (point without vegetation cover) at 32,5°C. The third highest average THI value is at Point B (point with grass cover) at 32,2°C. The lowest average THI value is at Point D (point with closely spaced planting) at 31,9°C. The THI value in the zone with vegetation cover is lower, averaging 32°C, while the zone without vegetation cover is 32,4°C, both zones fall into the uncomfortable category. The difference in THI values between these two points is 0,4°C.

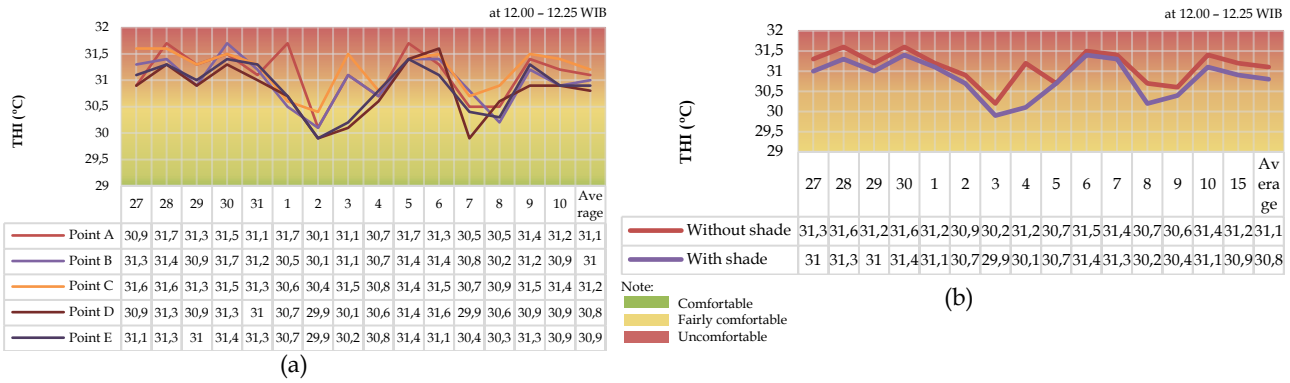
Here are the results of the air temperature and humidity measurements taken during the day at 16.30 – 16.55 WIB at Sudirman Field.

Table 12. Results of Temperature and Humidity Measurements at Sudirman Field at 16.30 – 16.55 WIB, Analysis (2024)

Date of Measurement	Temperature (°C)					Humidity (%)				
	TN			DN		TN			DN	
	A	B	C	D	E	A	B	C	D	E
27 May 2024	33,3	33,7	34,2	33,2	33,5	63,9	64,5	62,1	65,5	63,8
28 May 2024	34,1	33,7	34,0	33,5	33,6	64,9	65,2	65,1	66,6	66,0
29 May 2024	33,7	33,3	33,8	33,2	33,3	64,1	64,7	63,2	65,6	66,0
30 May 2024	33,9	34,0	33,8	33,6	33,7	65,1	65,6	66,2	66,0	66,6
31 May 2024	33,4	33,5	33,7	33,1	33,5	65,7	65,4	64,5	67,6	67,3
01 June 2024	34,1	32,8	32,9	32,9	32,9	64,3	65,7	65,5	67,3	66,6
02 June 2024	32,2	32,2	32,6	31,8	31,9	67,7	66,9	66,3	69,5	68,9
03 June 2024	33,3	33,3	33,8	32,2	32,3	66,5	66,3	65,7	67,7	67,0
04 June 2024	33,7	33,5	33,5	33,4	33,4	55,3	58,0	60,2	58,8	60,7
05 June 2024	34,2	33,7	33,8	33,6	33,7	64,1	65,5	64,7	67,9	66,0
06 June 2024	33,5	33,6	33,8	33,6	33,2	66,7	67,1	66,2	69,5	68,5
07 June 2024	32,6	32,9	32,9	31,8	32,5	68,1	67,8	67,1	69,8	68,2
08 June 2024	32,8	32,6	33,2	32,6	32,4	65,3	63,7	65,4	68,6	68,1
09 June 2024	34,2	33,9	34,2	33,5	34,0	59,2	60,2	60,0	60,8	60,5
10 June 2024	34,2	33,8	34,6	33,7	33,8	56,3	57,8	53,2	57,9	57,6
Average	33,5	33,4	33,7	33,0	33,2	63,8	64,3	63,7	65,9	65,5

Note: TN: Without shade, DN: With shade

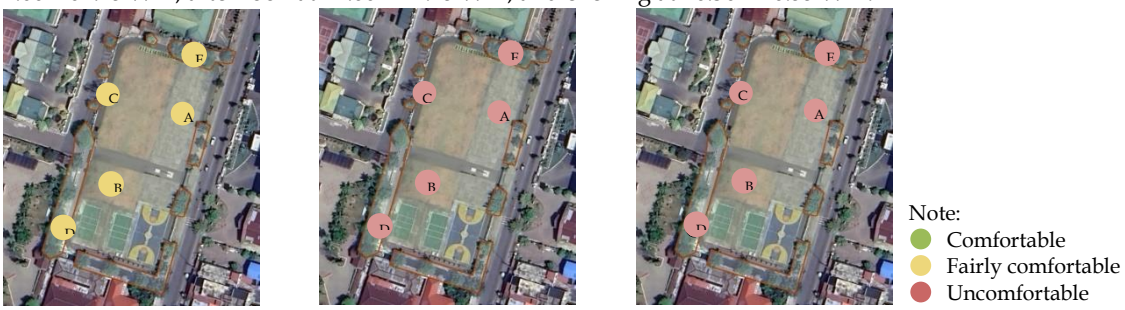
Below is the graph of the THI value calculations at Jenderal Sudirman Field in the afternoon at 16.30 – 16.55 WIB during the 15 days of measurement.



Graph 9. (a) Value of THI Sudirman Field at 16.30 – 16.55 WIB, (b) Difference in THI Values Sudirman Field at 16.30 – 16.55 WIB, Analysis (2024)

The graph above shows that the THI values during the afternoon measurement at Sudirman Field from 16.30 – 16.55 WIB, all measurement points fall into the uncomfortable category. The lowest average THI value is at point D (the point with closely spaced planting), which is only 30,8ºC. The highest average THI value is at point C (the point without vegetation cover), reaching 31.2ºC. The THI values in the vegetated zone are lower, with an average of 30,8ºC, while the zone without vegetation cover is at 31,1ºC, both of which fall into the uncomfortable category. The difference in THI values between these two points is 0,3ºC.

Here is a presentation of the THI value categories at each measurement point in Jenderal Sudirman Field during the morning at 07.00 – 07.25 WIB, afternoon at 12.00 – 12.25 WIB, and evening at 16.30 – 16.55 WIB.



(a) (b) (c)

Picture 6. Category of THI Values at Sudirman Field (a) Morning at 07.00 – 07.25 WIB, (b) Afternoon at 12.00 – 12.25 WIB, (c) Evening at 16.30 – 16.55 WIB, Analysis (2024)

Recapitulation of Thermal Comfort Data Based on THI

This recap aims to provide a more comprehensive overview of the comparison of Temperature-Humidity Index (THI) values in each measurement zone for each research sample.

Table 13. Recap of Thermal Comfort Data Based on THI in the Three Research Samples, Analysis (2024)

Sample	Zone	THI Values (°C)		
		Morning	Afternoon	Evening
Riyadhah Park	DN	29,3ºC	31,9ºC	30,7ºC
	TN	29,7ºC	32,5ºC	31,3ºC
	Average		30,7	
Hiraq Field	DN	29,5ºC	32,2ºC	30,7ºC
	TN	30ºC	32,6ºC	31,1ºC
	Average		30,9	
Sudirman Field	DN	29,7ºC	32ºC	30,9ºC
	TN	30ºC	32,4ºC	31,1ºC
	Average		31,1	

Note: TN: Without shade, DN: With shade

Note:
Comfortable
Fairly comfortable
Uncomfortable

Based on the measurements taken at three different time intervals over 15 days, the results for the THI values in the morning across the three research samples indicate that the vegetated zones in Riyadhah Park have an average THI value of 29,3°C, while the non-vegetated zones have an average THI of 29,7°C. For Hiraq Field, the vegetated zone has an average THI of 29,5°C, and the non-vegetated zone has a THI of 30°C. In Sudirman Field, the vegetated zone shows an average THI of 2,.7°C, while the non-vegetated zone also registers an average of 30°C. Overall, the THI values in the morning across all three research samples, in both zones, fall into the comfortable category.

Then, the average THI values obtained for the afternoon indicate that the vegetated zone in Riyadhah Park has a THI of 31,9°C, while the non-vegetated zone has a THI of 32.5°C. For Hiraq Field, the vegetated zone has a THI of 32,2°C, and the non-vegetated zone has a THI of 32,6°C. Meanwhile, in Sudirman Field, the vegetated zone has an average THI of 3,.2°C, and the non-vegetated zone has a THI of 32,4°C. Both zones in the three research samples fall into the uncomfortable

category for THI values during the afternoon.

Finally, for the afternoon measurements, the average THI values obtained are as follows: in the vegetated zone of Riyadhah Park, it is 30,7°C, and in the non-vegetated zone, it is 31,3°C. In Hiraq Field, the vegetated zone has a THI of 30,7°C, while the non-vegetated zone has a THI of 31,1°C. In Sudirman Field, the average THI in the vegetated zone is 30,9°C, and in the non-vegetated zone, it is 31,1°C. In all three research samples, both zones also fall into the uncomfortable category for THI values in the afternoon.

Conclusions

Based on the results of the research analysis, several conclusions have been drawn to explain thermal comfort conditions based on the Temperature Humidity Index (THI) in the research samples. From THI measurements taken at three different time intervals over 15 days, the following conclusions were obtained:

In the morning, the THI values at the three research locations Riyadhah Park, Hiraq Field, and Sudirman Field indicate that areas with vegetation cover have slightly lower THI values compared to areas without vegetation cover. The average THI for areas with vegetation cover ranges from 29,3°C to 29,7°C, while for areas without vegetation cover, it ranges from 29,7°C to 30°C. All zones in the morning fall into the fairly comfortable category.

In the afternoon, the difference in THI between areas with and without vegetation cover becomes more noticeable. The THI values in areas with vegetation cover at Riyadhah Park, Hiraq Field, and Sudirman Field each range from 31,9°C to 32,2°C. Areas without vegetation cover show higher values, ranging from 32,4°C to 32,6°C. All zones at the three locations during the afternoon fall into the uncomfortable category.

The measurements taken in the evening show a pattern similar to the afternoon, where zones with vegetation cover have a slightly lower THI compared to zones without vegetation cover. The average THI in zones with vegetation cover ranges from 30,7°C to 30,9°C, while zones without vegetation cover range from 31,1°C to 31,3°C. All zones across the three locations fall into the uncomfortable category in the evening.

Overall, zones with vegetation cover across the three research locations consistently show lower THI values compared to zones without vegetation cover. This indicates that the presence of vegetation can play a role in reducing temperature and improving thermal comfort, especially during times of higher heat intensity, such as in the afternoon and evening.

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