SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V12I10P103
Volume 12 Issue 10, 37-51, October 2025
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Original Article

Microclimate Variation and Thermal Comfort Analysis in Janeshwar Mishra Park, Lucknow: A Zonal Study of Hardscape, Softscape, Waterbody, and Shaded Areas

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Received: 03 August 2025 Revised: 05 September 2025 Accepted: 04 October 2025 Published: 31 October 2025

Abstract *- Microclimate within the park influences the usability of different spaces within the park. As different spaces have their own thermal comfort, it is necessary to know how thermal comfort in areas like Hardscape, Softscape, Waterbody, and Shaded structure behaves with and without tree cover. This study is based on field data comprising air temperature, relative humidity, globe temperature, wind speed, global radiation, and surface temperature for Asia's largest park in Lucknow, India. The simulated data presents PET and MRT with the help of the Rayman software, and the data of all the zones are compared based on the presence and absence of tree cover. The results suggest that the shaded structure has more thermal comfort than others, followed by the Softscape area, and there is a drastic difference in mean PET between with and without trees for the near water body and hardscape area.*

Keywords *- Microclimate, Thermal Comfort, Urban Park, Landscape Component.*

1. Introduction

Urban parks serve a critical function within urban environments, contributing significantly to the health and well-being of individuals across all age groups. It acts as a vital space for families to engage with the natural environment and experience the benefits of fresh air exposure [1]. In recent decades, the implementation of urban greening, particularly within urban parks, has emerged as a crucial strategy for addressing the challenges associated with urbanisation [2]. In the context of extreme heat in urban environments, the presence of greenery can significantly influence the microclimate and contribute to a reduction in air conditioning usage [3], as the urban population tends to engage in outdoor activities for extended periods. Because of this, many researchers have also tried to focus on open space at the city level [4], and alternative greens, as effectively designed and utilised outdoor space serves as the fundamental basis for achieving a thermally comfortable microclimate. The resultant microclimatic conditions exert influence on human physiology and psychology [5]. Thermal comfort is characterised as a state of mind that reflects an individual's satisfaction with the thermal environment [6], which is evaluated subjectively. Individuals in outdoor settings experience direct exposure to their immediate environment, which includes variations in sunlight and shade, fluctuations in wind speed, and other environmental characteristics. Consequently, individuals' perception of thermal comfort is significantly influenced by the surrounding microclimate conditions. The microclimate exerts a significant influence on the decision-making process regarding the utilisation of the space [7]. The size of a park has consistently been recognised as a significant variable affecting air temperature and comfort within the park environment. Furthermore, it has been demonstrated that tree coverage significantly impacts the microclimate within a park setting [8]. Various literature studies have been done on the cooling effects within the parks. However, a limited study has been done based on the different zoning within the park as a whole.

2. Review of Literature

Numerous studies have investigated the influence of various tree species on cooling effects, establishing correlations with species-specific characteristics such as leaf area index, tree size, and canopy structure [9], all of which are pertinent to the trees' capacity to intercept solar radiation. Research on grassed surfaces has demonstrated their cooling effect on both the ambient air [10] and surface temperatures. Grassed parks with a higher density of trees tend to maintain cooler temperatures compared to those with fewer trees [11]. Several studies have documented the cooling effect of water bodies located within park environments. Hathway and Sharples conducted an observation indicating that urban rivers in Sheffield, UK, may exert a cooling effect on the surrounding area [12]. A study has also been done on the impact of the urban

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component on pathways [13]. These studies have been done in different climatic zones around the world. Focusing on either the tree cover or the climatic conditions near the water body and pathways. There is a need to understand all the zones of the park and how it will change the microclimate with the presence and absence of tree cover. Also, the thermal comfort of different zones and scenarios in a park should be checked, and the comparison with and without tree cover should be made to know which area has more thermal comfort than others. So this study aims to understand the thermal comfort of microclimate variation within a park, comparing four zones: softscape area, hardscape area, waterbody, and shaded structure with and without a tree.

3. Study Area

This study was conducted in Lucknow, a rapidly expanding urban centre in northern India with a population of approximately 4.6 million [14]. Lucknow is characterised by significant climatic variability, experiencing scorching summers, cool, dry winters, and a well-defined monsoon season. According to the Köppen-Geiger classification, the city falls under the ‘Cwa’ (humid subtropical) climate type, distinguished by hot summers and dry winters [15, 16]. The National Building Code (NBC) of India further designates Lucknow as belonging to the Composite Climate Zone, which is typified by marked seasonal swings in temperature and humidity [17]. The city’s average annual rainfall is approximately 1214 mm, with recorded temperature extremes ranging from 6°C to nearly 48°C [18].

The selected study site is Janeshwar Mishra Park, situated in the Gomti Nagar area of Lucknow (26° 51' 13.14" N, 80° 59' 20.544" E). Covering 376 acres (1.52 km²), it is the largest urban park in Asia and serves as a vital green lung for the densely populated city [19]. Established in 2014, the park includes a mosaic of landscape elements such as extensive lawns (softscape), paved pathways (hardscape), interconnected lakes and canals, children’s play areas, gardens, and multiple gazebos and seating structures.

Janeshwar Mishra Park is bordered by residential neighbourhoods on one side and the Gomti River along its rear, making it both a community hub and an ecological corridor. The park contains a rich diversity of plant species, both indigenous and exotic, distributed across dense groves and open lawns, as well as aquatic habitats that support notable avian diversity. Previous studies have documented over 80 bird species within the park, highlighting its ecological significance [19].

The park is widely used by local residents for recreation, fitness, and relaxation, reflecting its importance in urban life. Its diverse physical layout and intensive public use make it an ideal case for studying microclimate and thermal comfort dynamics across varied park spaces. The city experiences three distinct seasons: summer, monsoon, and winter. The average annual precipitation is approximately 1214.17 mm, with a recorded maximum temperature of 48 °C and a minimum temperature of 6 °C. The months characterised by the highest temperatures are May and June, while those with the lowest temperatures are December and January [18].

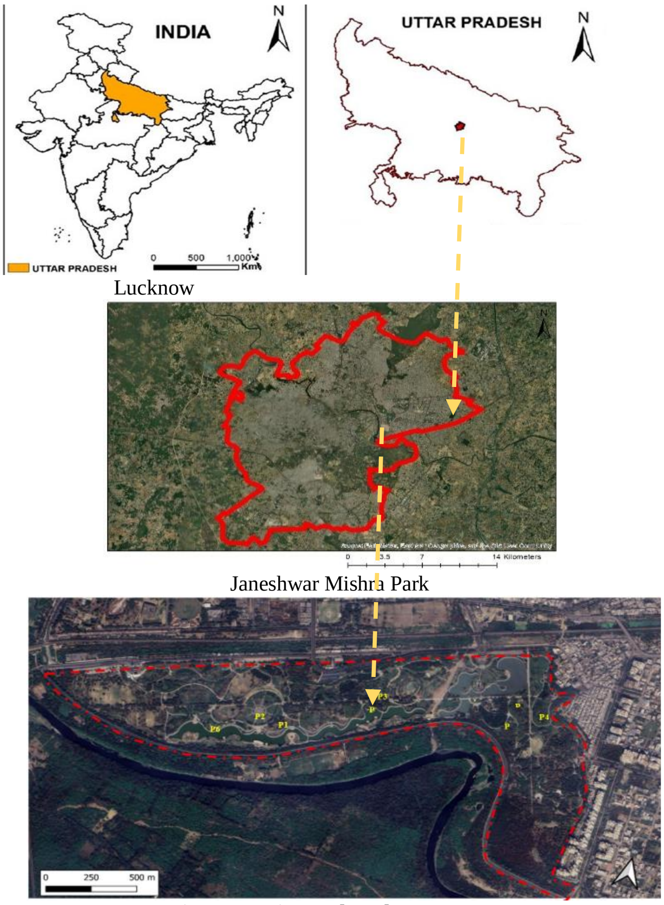


Fig. 1 Location and study area map

4. Materials and Methods

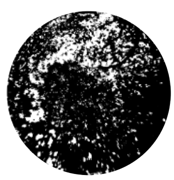
Two levels of analysis were done to understand the thermal comfort within a park. One focuses on the survey data with 138 respondents, with the questions focusing on thermal comfort inside and outside of the park, differences within different areas of the park, and what their preferred comfortable space within the park is. And the other method was to analyse 4 types of areas: softscape area, hardscape area, waterscape or water body area, and manmade shaded structures like gazebo and trellis area, which affect the microclimate within the park, and in a total of 8 scenarios, give more accurate variations in the park for the accurate study. Then, these areas were further divided into zones with trees and without trees, and a microclimatic study was conducted to understand thermal comfort. The Air temperature, Mean Radiant Temperature (MRT), and Psychological Equivalent Temperature (PET) were studied and compared within these eight selected areas, and also the temperature change analysis was done to understand the change in temperature by the addition of the tree cover. The district-level park in Lucknow was selected as the study area. The Rayman software was used to study MRT and PE to simulate data received from the different zones [20]. The metabolic rate and clothing used for the simulation for thermal comfort are for resting conditions, not for excessive activity, and are given in Table 1. The data were obtained from the equipment listed below, which was installed approximately 1.5 meters above ground level. The study focused on three particularly warm days during the summer, specifically the 14th, 15th, and 16th of May in the year 2025, capturing the microclimatic variation and thermal comfort conditions across different park environments, including hardscape, softscape, near water, and gazebo areas, with and without tree shade. RayMan was used as a simulation tool using the collected data, with an emphasis on microclimatic parameters that affect thermal comfort [21-24]. The model computes critical indices such as the Mean Radiant Temperature (MRT) and Physiological Equivalent Temperature (PET), which are extensively utilised in the field of urban climate research. The model represents components, including buildings and vegetation, as static obstacles in the computation of indices such as shadow effects and Sky View Factor (SVF), along with several solar radiation indices [25]. Materials used are given in Table 1. The collected data for all the selected points are given in Appendix 1-8.

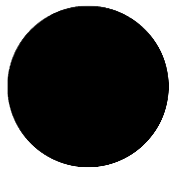
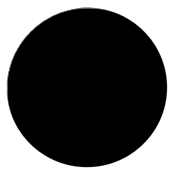
Table 1. Data used and its sources

Data	Source
Air Temperature	Primary data from selected points (Instrument- Heat Stress WBGT Meter- WBGT-188D)
Humidity	Primary data from selected points (Instrument- Heat Stress WBGT Meter- WBGT-188D)
Globe Temperature	Primary data from selected points (Instrument- Heat Stress WBGT Meter- WBGT-188D)
Wind Speed	Primary data from selected points (Instrument -Metravi Multifunction smart anemometer)
Global Radiation	Primary data from selected points (Instrument- Solar Power Radiation Meter W/m²)
Surface Temperature	Primary data from selected points (Instrument – Laser infrared thermometer)
Simulation-PET	Rayman Software
Park Map	Google Earth
Metabolic Rate	80 W
Clothing	0.60 clo

The data was collected in 8 locations of four zones with and without trees. The photo of the location of data and SVF is given in Table 2.

Table 2 Site image of data collection location in the park

Points	Site image	Description	SVF Photo	SVF
1		Hardscape With Tree		0.30
2		Hardscape Without Tree		0.97
3		Softscape With Tree		0.2

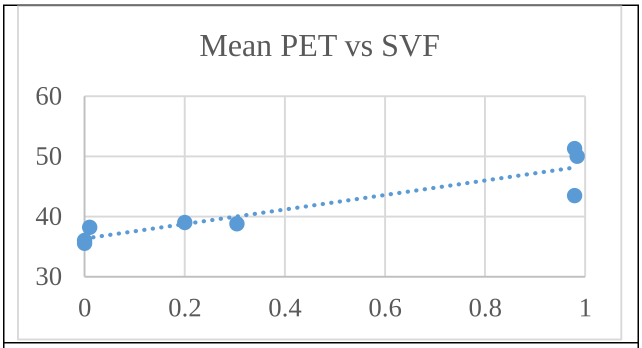
4		Softscape Without Tree		0.97
5		Waterbody with tree		0.01
6		Waterbody without Tree		0.98
7		Shaded Structure with a tree		0
8		Shaded structure without a tree		0

5. Results

The Skyview factor of all the scenarios is correlated with the mean PET and value received, r=0.919, which shows a high correlation of PET with SVF. This is also explained in many earlier studies. The correlation is shown in Table 3

Table 3. Correlation between SVF and mean PET

	SVF	Mean PET
Constructed Shade with Tree cover	0	35.58846
Constructed shade without tree cover	0	36.04231
Hardscape without a tree	0.979	51.34919
Hardscape with tree cover	0.304	38.81938
Softscape with tree cover	0.2	39.04615
Softscape without a tree	0.979	43.49535
Near a water body with trees	0.01	38.22346
Near a water body without trees	0.984	50.04554



r= 0.919

In terms of the Sky View factor, it is clear that a clearer sky or less canopy cover will increase the PET level. However, it is unable to tell the differences in the comfort range within the different types of zones in parks with and without tree cover. So the area-wise study of microclimatic comfort is done to understand the variation.

5.1. Area-Wise Microclimate Study

A total of 4 zonal types were selected, and their microclimatic analysis, based on Air temperature, MRT, and PET, was analyzed in two scenarios: with and without tree cover. The four zones are Softscape area, Hardscape Area, Area near waterbody, and in constructed shades.

5.2. Mean Radiant Temperature (MRT)

The MRT for all three zone types of Softscape, Hardscape, and near water bodies without trees was more than 40℃ most of the day, whereas only for the softscape area it was below 40℃ till morning 8:30 am and after 5:30 pm. For the shaded area in both scenarios, with and without a tree, it ranges from 30℃ to 40℃ most of the time. The MRT variation is shown in Figure 2.

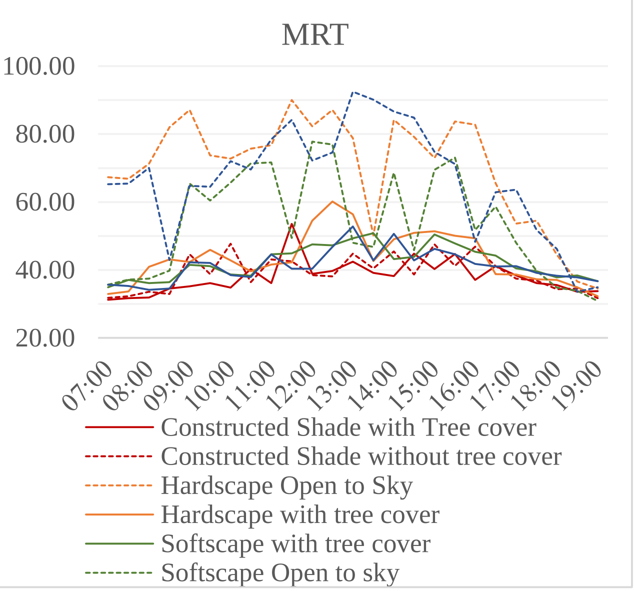


Fig. 2 Mean Radiant Temperature of different zones of the park at different time intervals

5.3. Psychological Equivalent Temperature (PET)

Psychological Equivalent Temperature comfort range, as per R. Kotharkar, the comfortable range falls between 27.65°C and 32.25°C, and from 32.25°C to 38.17°C feels slightly warm [26]. The range of PET simulated in Rayman shows that only a shaded structure with a bench provides a comfortable range in the morning between 7.00 am and 8.30 am. Shaded space both with and without a tree, softscape with a tree, near a waterbody area with a tree, comes in range on slightly warm in the morning from 7.00 am to 10.30 am. In an evening shaded structure, the hardscape with a tree, the water body with a tree, and the softscape without a tree have a slightly warm range of PET. The rest of the area felt warm and unbearable for the rest of the day. The PET Variation of all zones with different time intervals is shown in Figure 3.

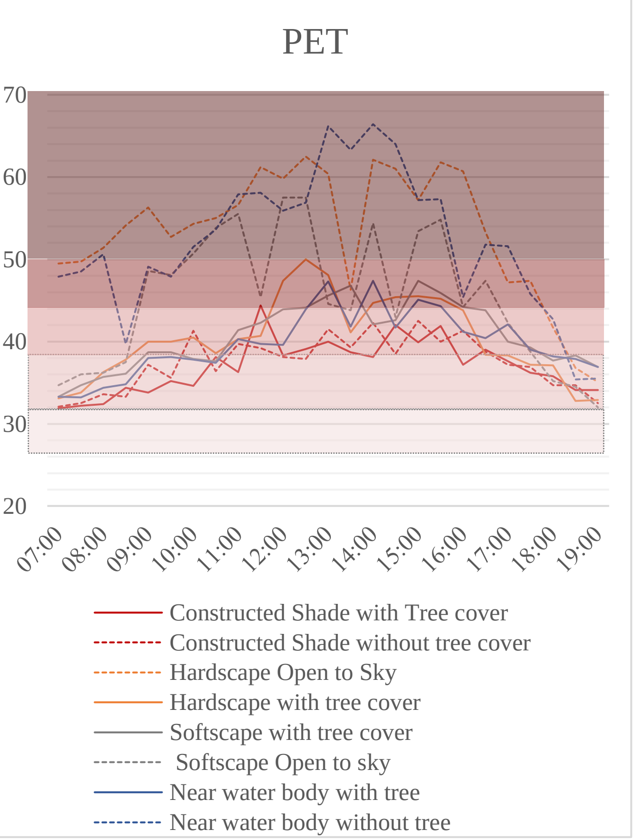
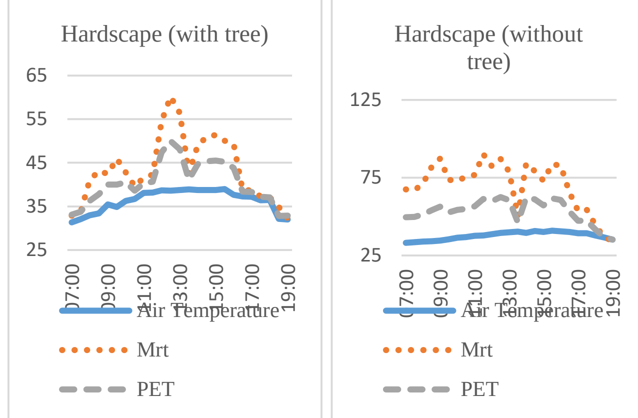


Fig. 3 PET of different zones of the Park at different time intervals

5.4. Hardscape Area

In the hardscape area, the mean air temperature is 36.37°C for the area with a tree and 37.66°C for the area without a tree. However, in MRT, there is a lot of difference, ranging from 43.55°C with a tree and 70°C without a tree. There is a 13°C change in mean PET of the area with a tree, having 40.36°C, compared to the area without a tree, having 53.36°C. The PET ranges from 31.4°C to 40.5°C until 10:30 am with tree and from 49.5°C to 54.40c till morning. The Air Temp., MRT, and PET variation in the Hardscape area with and without a tree is given in Table 4.

Table 4. Air Temp., MRT, PET Variation In Hardscape Area With And Without Tree



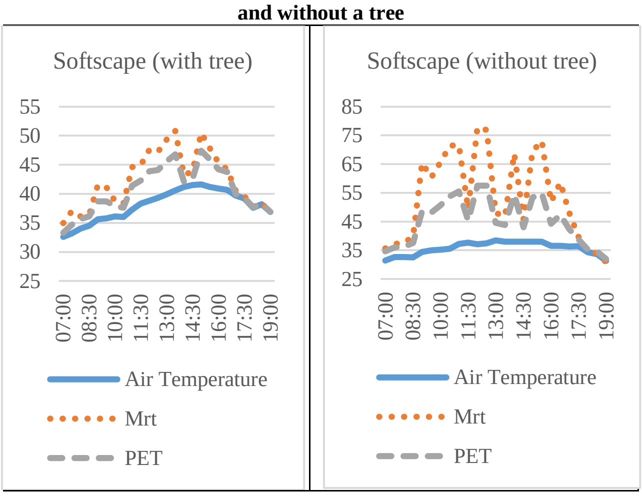
	Air Temp.	Mrt	PET
Hardscape (with tree)	36.372	43.55	40.36
Hardscape (without tree)	37.668	70.17	53.36

Air temperature, MRT, and PET difference with and without a tree in the hardscape surface		
Air Temperature	MRT	PET
1.29	26.26	13.00

5.5. Softscape Area

Softscape means the air temperature in an area with tree cover is 38.02°C, and without tree cover is 35.68°C. But the MRT with tree cover is 42.26°C compared to 53.53°C without trees. There is a 5°C change in mean PET, having 40.6°C with the tree and 45.19°C without the tree. The minimum PET with tree is 33.3°C, which goes up to 46.8°C at 2.00 pm. It has a comfortable range in the morning and goes slightly warm with 37.6°C at 10.30 am with the tree and 53.8°C without the tree. The Air Temp., MRT, and PET variation in the softscape area with and without a tree is given in Table 5.

Table 5. Air temp.. MRT, PET variation in the softscape area with and without a tree



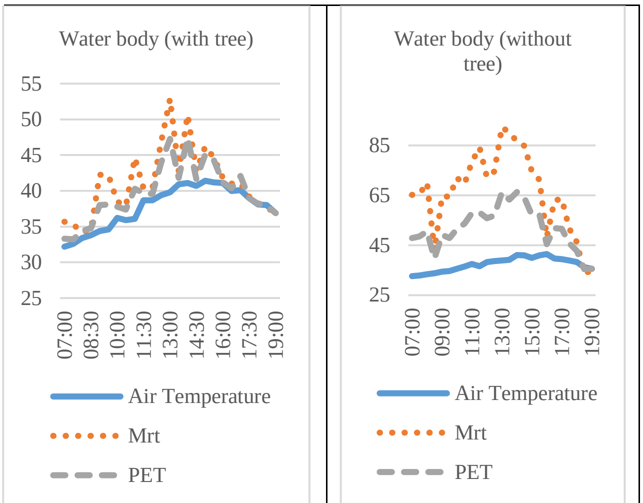
	Air Temperature	Mrt	PET
Softscape (with tree)	38.028	42.26	40.6
Softscape (without tree)	35.68	53.53	45.19

Air temperature, MRT, and PET difference with and without a tree in the softscape surface		
Air Temperature	MRT	PET
-2.34	11.27	4.59

5.6. Waterbody

The Waterbody area with a tree has an almost similar air temperature of 37.77°C with the tree and 37.40°C without the tree. The MRT difference is 25.47°C at 41.14°C with the tree and 66.61°C without the tree. The mean PET level with tree falls in a slightly warm range, having 39.75°C, and extremely hot, having 52°C, in an area without trees. The Air Temp., MRT, and PET variation near the waterbody area with and without a tree is given in Table 6.

Table 6. Air temp.. MRT, PET variation near the waterbody area with and without a tree



	Air Temperature	Mrt	PET
Waterbody (with tree)	37.77	41.14	39.7
Waterbody (without tree)	37.40	66.61	52.00

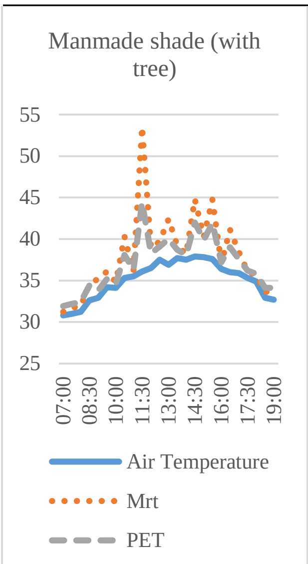
Air temperature, MRT, and PET difference with and without a tree near the waterbody area		
Air Temperature	**MRT**	**PET**
-0.36	25.47	12.25

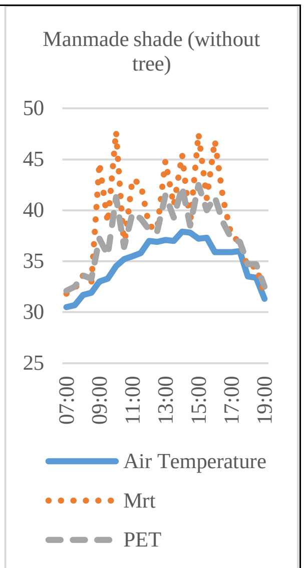
5.7. Shaded Structure (Gazebo)

Manmade shaded structures have an air temperature of 35.08°C with a tree and 34.88°C without a tree. In terms of

MRT, it is 37.97°C with tree cover and 39.26°C without tree cover. In terms of PET with and without the tree, it is 37.01°C and 37.48°C, respectively. This area falls under the comfort range in the morning and late evening. The Air Temp., MRT, and PET variation in shaded structure area with and without a tree is given in Table 7.

Table 7. Air temperature MRT, PET variation in the shaded structure area with and without a tree





	Air Temperature	**Mrt**	**PET**
Shaded structure (with tree)	35.08	37.97	37.01
Shaded structure (without tree)	34.88	39.26	37.48

Air temperature, MRT, and PET difference with and without a tree near the shaded structure area		
Air Temperature	**MRT**	**PET**
-0.2	1.29	0.47

5.8. Survey Analysis of Thermal Comfort within a Park

The park survey was done with 138 respondents, 84 males (60.87%) and 54 females (39.13%). The questions were asked on the basis of the temperature difference between inside and outside of the park, thermal comfort within different zones of the park, and what their preferred comfortable space within a park would be.

In terms of the thermal comfort in the park compared to outside, 63.77% felt cooler in the park 15% felt hotter in the park, and 15% felt no difference. Within the park, there was a difference in the comfort level and temperature because of the microclimatic variation. As a result, 54.35% felt cooler at some places, whereas 28.99% felt hotter, and the rest felt no difference.

As there was a temperature difference within the park, user also felt and gave their perception of a comfortable space within the park. Most preferred space to visit within a park was space with dense tree cover, with 29% response, 24.54% preferred near a water body, 17.47% preferred a shaded area with a bench, 9.67% lawn area, 5.95% preferred a paved plaza, and the rest preferred to walk and run within the park.

Preferred time to visit is mostly evening and late evening, accounting for 60% and 27.66% in the early morning. Afternoon and morning are not preferred times.

6. Discussion

Comparing the thermal comfort at the 4 zones that are the Hardscape area, the Softscape area, the near waterbody area, and the area with shaded structure within the park, with two scenarios having tree cover and without tree cover, gave us a clear understanding of which area has more thermal comfort in comparison to others. The result also shows that the areas provided with tree cover have an influence on the thermal comfort level. Within the 4-zone area, the shaded structures have a more comfortable level than the other zones with minimum PET as 31.9°C and 32.1°C, and mean PET 37°C and 37.4°C for with tree and without tree, respectively. Softscape area with and without tree have comfortable and slightly warm range in early morning and evening, respectively, but without tree cover softscape has warm level to very hot in other times of the day, its minimum PET is 33.1°C and 33.3°C and mean PET is 40.36°C and 40.6°C which is almost similar in both the cases of with tree and without tree. A hardscape area with a tree has a comfortable level in the early morning and evening, but a hardscape area without a tree is only comfortable in the late evening after sunset. Areas near a water body with trees are comfortable in the early morning and late evening, but slightly warm in the late morning and early evening. The water body area without trees is not comfortable throughout, but has a very contrasting difference of PET, which is in the morning has 33.3°C with trees and 47.9°C without trees, but has cooler PET in the evening, having 36.9°C with trees and 35.5°C without trees. The least difference has been seen in the shaded area PET and MRT difference between with and without tree, then the softscape area with 4.59°C and 11.27°C, respectively. Third is a water body with an MRT difference of 25.47°C and a pet difference of 12.25°C, and last is a large difference of 26.26°C and 13°C, respectively, for the hardscape area.
For shaded structures with and without trees, softscapes with trees are the only area that has very little variation of MRT and PET with air temperature. The rest of the zones and scenario areas have a large difference compared to the air temperature of the area.

7. Conclusion

In earlier research and methods, the overall microclimate or the green cover within the park was only discussed; this study has concluded that there is a variation of thermal comfort within the different zones, having different elements with and without trees.

With the current study, it is clear that trees reduce the air temperature, MRT, and PET of the area, very little in the case of softscape but more in the case of hardscape and near a water body. Trees do not create microclimate change near shaded structures, so they can be placed as a seating option near the lawn and water body. Dense tree cover should be provided near the water body and hardscape surface to decrease the PET level during the users' preferred visit time. As different areas have different microclimatic zones and are affected by tree cover, this should be studied further to determine how much hardscape, softscape, and water body should be provided in a park to achieve maximum thermal comfort.

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Appendix

Appendix 1 Data readings to calculate PET and MRT for the Hardscape area with a tree

Hardscape With Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	31.4	32.9	50.2	0	97.3	31	32.90	33.1
07:30	32.1	33.7	49.7	0	98.8	31	33.70	33.8
08:00	33	35	44.4	0.9	103.4	32	40.98	36.3
08:30	33.4	36	44.5	0.8	133.4	32	43.13	37.8
09:00	35.5	42.4	38.6	0	470.4	32	42.40	40
09:30	34.9	37.5	40.1	1.1	106.1	30	45.96	40
10:00	36.3	42.8	37.3	0	121.9	32	42.80	40.5
10:30	36.7	39.6	36.3	0	129.6	32	39.60	38.6
11:00	38.1	41.6	32.9	0	153	32	41.60	40.3
11:30	38.2	42.3	30.4	0	134.6	33	42.30	40.7
12:00	38.7	43.2	32.8	0.8	383	33	54.51	47.4
12:30	38.6	44.3	30.7	1	328.4	35	60.17	50
13:00	38.8	43	30.6	1.2	259.9	37	56.36	48.1
13:30	38.9	42.6	30.7	0	381.2	37	42.60	41.1
14:00	38.8	41.5	31.8	0.9	241	33	49.03	44.7
14:30	38.8	41.2	30.9	1.7	90.7	34	50.93	45.4
15:00	38.8	41.1	29.4	2	81.5	35	51.36	45.5
15:30	39	41.4	29.3	1.4	84.8	35	50.09	45.2
16:00	37.7	40.2	35.8	1.4	72.8	33	49.33	43.8
16:30	37.3	38.8	37.4	0	65.8	33	38.80	38.4
17:00	37.2	38.7	38.3	0	38.9	33	38.70	38.3
17:30	36.4	37.3	39.9	0	32.9	32	37.30	37.2
18:00	36.5	37.1	40.1	0	19.1	32	37.10	37.1
18:30	32.2	32.8	46.8	1.1	7.2	32	34.91	32.8
19:00	32	32.3	44.8	0	0	31	32.30	32.9

Appendix 2 Data readings to calculate PET and MRT for the Hardscape area without a tree

Hardscape Without Tree								
Time	Air temperature (TA)	Black globe temperature (TG)	Humidity (RH)	Wind Speed	Global Radiation	Surface Temperature	MRT	PET
	°C	°C	%	m/s	W/m²	Ts	°C	°C
07:00	33.2	42.4	33.1	1	274.6	31	67.37	49.5
07:30	33.5	42.9	32.4	0.9	473.1	34	66.85	49.7
08:00	33.9	43	31.7	1.3	537.2	34	71.31	51.4
08:30	34.1	42.5	31.1	2.8	684.2	36	81.99	54.1
09:00	34.5	43.2	30.2	3.3	702.1	40	87.14	56.3
09:30	35.3	43.2	28.1	1.9	792.6	39	73.69	52.7
10:00	36.3	45.3	26.9	1.3	883.1	44	72.82	54.3
10:30	36.9	44.6	28.7	2.1	958.5	49	75.68	55
11:00	37.7	45.9	27.7	1.9	1025.2	51	76.74	56.6
11:30	37.9	46.1	27.2	3.8	1024.8	52	90.04	61.2
12:00	38.7	47.1	24.7	2.4	1032.5	55	82.34	59.8
12:30	39.4	48.1	24	2.8	1022.5	53	87.10	62.5
13:00	39.9	49.2	23	1.5	991.8	56	78.83	60.4
13:30	40.4	50.2	22.9	0	959.3	56	50.20	46.3
14:00	39.5	49	22.5	2	870.2	54	84.14	62.1
14:30	40.7	49.4	24	1.7	796.1	55	79.21	61
15:00	40.2	47.4	24	1.7	664.5	54	73.00	57.2
15:30	40.9	47.6	23.2	3.7	598.3	50	83.73	61.8
16:00	40.5	46.9	23	3.9	445.5	49	82.78	60.7
16:30	40.1	45.5	22.4	1.7	375.1	47	65.54	53.3
17:00	39.3	43	23.9	1	239.6	43	53.68	47.2
17:30	39.2	42.7	25.8	1.3	172.2	41	54.50	47.4
18:00	37.9	39.4	27.7	1.2	67.8	38	44.53	41.7
18:30	36.6	36.6	30.8	0	23.7	37	36.60	36.8
19:00	35.1	34.5	34.9	0	0.1	35	34.50	35.1

Appendix 3 Data readings to calculate PET and MRT for the Softscape area with a tree

Softscape with Tree								
Time	Air temperature (TA)	Black globe temperature (TG)	Humidity (RH)	Wind Speed	Global Radiation	Surface Temperature	MRT	PET
	°C	°C	%	m/s	W/m²	°C	°C	°C
07:00	32.6	33.2	43.2	0.8	92.5	24	34.94	33.3
07:30	33.2	34.2	43.4	0.8	94.3	24	37.05	34.7
08:00	34	36.1	41.6	0	97	24	36.10	35.7
08:30	34.5	36.4	41.6	0	98.3	25	36.40	36.1
09:00	35.6	37.1	40.2	0.9	98.5	25	41.53	38.7

09:30	35.8	37.4	37.2	0.6	99.1	25	41.11	38.7
10:00	36.1	38.7	37.7	0	99.7	26	38.70	37.9
10:30	36	38.3	35.1	0	90.4	26	38.30	37.6
11:00	37.3	39.1	35.8	1	106.9	27	44.62	41.4
11:30	38.3	40.1	30.6	0.8	106.5	27	44.90	42.3
12:00	38.8	41.1	26.8	0.9	101.5	27	47.57	43.9
12:30	39.3	41.2	25.7	1.1	103	28	47.24	44.1
13:00	39.9	42.4	25.7	0.9	110.7	29	49.33	45.6
13:30	40.6	43.2	23.9	1	120.5	29	50.80	46.8
14:00	41.2	43.2	21.9	0	94.3	29	43.20	42.1
14:30	41.5	43.9	21.3	0	463.8	31	43.90	42.6
15:00	41.6	44.1	21.9	0.8	124.2	30	50.48	47.4
15:30	41.2	42.8	21.7	1.1	102.4	30	47.83	45.9
16:00	40.9	42.2	19.3	0.7	61.1	32	45.36	44.2
16:30	40.7	41.5	19.3	1.2	48.6	29	44.21	43.8
17:00	39.7	40.5	21.8	0	36.8	30	40.50	40
17:30	39.2	39.6	22.6	0	16.4	26	39.60	39.3
18:00	37.6	37.8	26.9	0	9.1	26	37.80	37.7
18:30	38.2	38.4	26.2	0	4.4	25	38.40	38.3
19:00	36.9	36.7	28.7	0	0	25	36.70	36.9

Appendix 4. Data readings to calculate PET and MRT for the Softscape area without a tree

Softscape without Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	31.4	35.7	45.7	0	325.1	28	35.70	34.7
07:30	32.6	37.2	46.5	0	357.2	29	37.20	36
08:00	32.7	37.5	46.8	0	363.3	29	37.50	36.2
08:30	32.5	39.8	48.2	0	402.5	31	39.80	37.5
09:00	34.4	41.5	43	1.4	552.9	33	65.40	48.6
09:30	35	42.8	46	0.7	597.2	33	60.43	48.1
10:00	35.2	43.8	44.8	0.9	714	34	65.74	50.7
10:30	35.5	45.4	44.1	1	770.2	35	71.42	53.8
11:00	37.2	47.2	41.9	0.9	799.5	37	71.65	55.5
11:30	37.7	49.4	43.5	0	820.9	38	49.40	45.4
12:00	37.1	46.7	42	1.5	851	38	77.77	57.5
12:30	37.4	47	41.5	1.4	822.1	35	76.89	57.5
13:00	38.4	48	40.4	0	779.8	37	48.00	44.6
13:30	38	46.8	42.1	0	818.1	37	46.80	43.8
14:00	38	46.8	38.1	0.9	735.1	37	68.66	54.4
14:30	38	45.8	36.5	0	629.8	34	45.80	43

15:00	38	44.4	39.7	1.9	553.7	35	69.46	53.4
15:30	38	44.6	40.7	2.3	526.3	33	73.07	54.8
16:00	36.5	40.2	47	1.1	393.2	32	51.76	44.2
16:30	36.6	41.7	46.2	1.3	327.2	32	58.63	47.4
17:00	36.3	39.1	47	1.1	189.3	32	48.05	42.3
17:30	36.4	39.7	48.3	0	147.7	29	39.70	38.8
18:00	34.3	34.8	53.7	0	46.5	26	34.80	35.2
18:30	33.7	33.9	56.1	0	31.6	25	33.90	34.5
19:00	31.3	30.9	64.3	0	0	23	30.90	32

Appendix 5 Data readings to calculate PET and MRT for the near waterbody area with a tree

Near a waterbody with a Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	32.2	33.1	43.6	0.8	72.7	27	35.70	33.3
07:30	32.6	33.2	43.8	1.1	75.2	27	35.30	33.2
08:00	33.4	34.2	43.4	0	76.8	27	34.20	34.4
08:30	33.8	34.5	43.2	0	83.2	28	34.50	34.8
09:00	34.4	36.3	42.7	1	85.4	29	42.28	38
09:30	34.6	36.5	40.3	0.9	94.5	29	42.11	38.1
10:00	36.2	38.5	35.6	0	111.1	30	38.50	37.8
10:30	35.9	37.9	36.8	0	72.4	28	37.90	37.4
11:00	36.1	38.1	37.4	1.1	82.5	29	44.63	40.3
11:30	38.7	40.4	27.5	0	86.2	30	40.40	39.7
12:00	38.7	40.4	24.9	0	90.4	30	40.40	39.6
12:30	39.4	41.7	24.5	0.6	94.3	30	46.78	43.9
13:00	39.8	43.5	25.5	0.8	94.3	30	52.86	47.3
13:30	40.9	42.8	25.1	0	99.8	31	42.80	41.8
14:00	41.1	42.9	21.2	1.9	88.3	31	50.65	47.4
14:30	40.7	42.8	25.3	0	73.3	32	42.80	41.7
15:00	41.4	42.8	22.9	0.7	110.5	31	46.18	45.1
15:30	41.2	42.1	20.8	0.9	53.5	30	44.66	44.3
16:00	41.1	41.8	19.4	0	42.4	32	41.80	41.2
16:30	40	41	21.8	0	27.4	30	41.00	40.4
17:00	40.1	40.3	20.3	1.5	20.2	28	41.09	42.1
17:30	39	39.2	22.7	0	8.3	28	39.20	39
18:00	38.1	38.3	26.4	0	5.7	27	38.30	38.2
18:30	38	37.8	25.8	0	2.3	28	37.80	37.9
19:00	36.9	36.7	28.4	0	0	27	36.70	36.9

Appendix 6 Data readings to calculate PET and MRT for the near waterbody area without trees

Near a waterbody without a Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	32.6	41.3	33.4	1	296.4	30	65.26	47.9
07:30	32.9	42	33.7	0.9	485.3	32	65.44	48.5
08:00	33.4	42.6	34	1.2	536.2	34	70.08	50.6
08:30	33.8	42.9	34.6	0	758.2	34	42.90	39.7
09:00	34.4	42.5	35.8	1	816.1	37	64.75	49.1
09:30	34.6	41	35.1	1.6	824.3	38	64.49	47.9
10:00	35.5	42.3	31.4	2.3	887.1	45	72.07	51.5
10:30	36.5	46	28.4	0.9	976.8	47	69.58	53.6
11:00	37.5	46.9	28.8	1.6	1030.9	45	78.41	57.9
11:30	36.6	45.1	32.1	2.8	1037.2	46	84.21	58.1
12:00	38.3	47	26.4	1.2	1037.1	45	72.23	55.9
12:30	38.6	47	23.5	1.5	1007.8	51	74.56	56.9
13:00	38.9	50.7	23.2	2	985.4	48	92.44	66.2
13:30	39.1	47.9	24.7	3.2	931.4	47	90.10	63.3
14:00	41.1	53.6	24.1	1.2	884.2	48	86.61	66.4
14:30	41	50.4	23.5	2	760.2	48	84.85	64
15:00	39.9	46.4	24.6	2.4	700.4	45	74.72	57.2
15:30	41	48	24.2	1.5	578.9	44	71.22	57.3
16:00	41.4	48.3	23.7	0	481.7	40	48.30	45.4
16:30	39.7	44.7	25.2	1.6	342.3	38	62.88	51.8
17:00	39.4	43.7	31	2.4	247.2	36	63.66	51.6
17:30	38.9	41.2	28.3	2.1	146.8	33	51.75	45.8
18:00	38.2	39.9	29	1.4	79.3	32	46.21	42.7
18:30	36.2	35.5	32.3	0.7	2.4	29	33.64	35.4
19:00	35.6	34.9	34.3	0	0.2	29	34.90	35.5

Appendix 7. Data readings to calculate PET and MRT for the shaded structure area with a tree

Shaded structure with a Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	30.8	31.2	48.7	0	6.1	29	31.20	31.9
07:30	31	31.7	48.2	0	6.3	29	31.70	32.2
08:00	31.2	31.9	48.6	0	6.7	28	31.90	32.4
08:30	32.6	34.5	49	0	8	28	34.50	34.4
09:00	32.9	33.5	48.9	0.8	8.6	28	35.23	33.8
09:30	34.2	36.1	48.5	0	10	29	36.10	35.2

10:00	34.1	34.8	48.7	0	10.3	29	34.80	34.6
10:30	35.3	36.7	45.3	0.7	12.1	29	40.28	38.1
11:00	35.5	36.1	45.6	0	12.7	29	36.10	36.3
11:30	36.1	39.9	43.6	1.4	13.3	30	53.53	44.4
12:00	36.5	37.1	45.1	0.9	13.7	30	38.89	38.3
12:30	37.5	39.7	44.4	0	13.6	30	39.70	39.1
13:00	36.9	37.8	42.8	2.3	12.7	30	42.43	40
13:30	37.7	39.2	38.8	0	11.2	32	39.20	38.7
14:00	37.5	38.2	40.3	0	10.9	32	38.20	38.1
14:30	37.9	39.6	37.9	1	9.2	32	44.80	42
15:00	37.8	38.5	41.1	0.7	8.4	31	40.28	39.9
15:30	37.6	39.8	42.9	0.6	6.1	32	44.75	41.9
16:00	36.4	37.1	47.9	0	5.9	32	37.10	37.2
16:30	36	37.3	48.6	0.9	4.1	32	41.14	39
17:00	35.9	36.5	47.7	1	3.4	32	38.42	37.6
17:30	35.3	36.1	51.3	0	1.4	31	36.10	36.2
18:00	34.9	35.6	51	0	1	32	35.60	35.8
18:30	32.9	33.6	59.8	0	0	31	33.60	34.1
19:00	32.7	33.8	60.1	0	0	31	33.80	34.1

Appendix 8. Data readings to calculate PET and MRT for the shaded structure area without the tree

Shaded structure without a Tree								
Time	**Air temperature (TA)**	**Black globe temperature (TG)**	**Humidity (RH)**	**Wind Speed**	**Global Radiation**	**Surface Temperature**	**MRT**	**PET**
	°C	**°C**	**%**	**m/s**	**W/m²**	**°C**	**°C**	**°C**
07:00	30.5	31.8	50.4	0	14.6	28	31.80	32.1
07:30	30.7	32.3	51.8	0	15.2	28	32.30	32.5
08:00	31.7	33.6	51.1	0	15.4	29	33.60	33.6
08:30	31.9	32.9	49.6	0	17.2	29	32.90	33.3
09:00	33	35.2	48.3	1.7	23.1	29	44.65	37.2
09:30	33.3	34.6	49.2	1	23.8	29	38.79	35.6
10:00	34.5	38.6	46.9	0.6	28.4	30	47.75	41.3
10:30	35.2	36.4	46	0	28.1	30	36.40	36.4
11:00	35.5	37.8	47.7	0.6	30.8	30	43.07	39.7
11:30	35.8	37.2	43.6	1.4	30.9	30	42.56	39.2
12:00	37	38.5	44.1	0	30.4	32	38.50	38.1
12:30	36.9	38.1	45.7	0	30.1	31	38.10	37.9
13:00	37.1	39	42.8	1	31.2	32	44.83	41.5
13:30	37	37.6	38.5	2	12.4	32	40.47	39.3
14:00	37.9	39.4	38	1.6	28.7	32	45.47	42.3
14:30	37.8	38.7	37.3	0	27.7	32	38.70	38.5
15:00	37.2	39.1	42	1.9	25.5	32	47.55	42.5

15:30	37.3	38.2	42.9	1.1	23.8	32	41.19	40
16:00	35.9	38.3	47.7	1.3	18.4	32	46.86	41.3
16:30	35.9	37.1	47.6	1.1	17	32	41.10	38.8
17:00	35.9	37.5	47.3	0	9.9	32	37.50	37.2
17:30	36	36.9	47.4	0	7.1	32	36.90	36.9
18:00	33.5	34.4	57.2	0	1.6	32	34.40	34.7
18:30	33.4	34.5	57.7	0	0.6	32	34.50	34.7
19:00	31.3	31.7	65	0	0	31	31.70	32.5