Contents available at: www.repository.unwira.ac.id

ARTEKS
JURNAL TEKNIK ARSITEKTUR

https://journal.unwira.ac.id/index.php/ARTEKS

Research paper

doi: 10.30822/arteks.v9i3.3298

Analyzing surface temperature on street median parks in Malang's hot-humid climate

Wasiska Iyati*, Ayu Nur Izzati Hilmy, Rika Nur Fitriani, Alya Nafisa Fidelista, Jono Wardoyo

Department of Architecture, Faculty of Engineering, Universitas Brawijaya Malang, East Java, Indonesia

ARTICLE INFO

Article history:
Received March 22, 2024
Received in revised form Aug. 18, 2024
Accepted November 09, 2024
Available online December 01, 2024

Keywords:
Green open space
Hot-humid climate
Street median parks
Surface temperature
Thermal image

***Corresponding author**: Wasiska Iyati
Department of Architecture, Faculty of Engineering, Universitas Brawijaya Malang, East Java, Indonesia
Email: wasiska.iyati@ub.ac.id
ORCID: https://orcid.org/0000-0002-9236-0307

ABSTRACT

In hot humid cities, the local microclimate can be moderated by the green open spaces. Differences in the characteristics of its hardscape and softscape elements can result in different thermal environmental conditions. As one of the green open spaces, the street median park can provide vegetation to reduce the air temperature of the region's microclimate. This paper analyzes the thermal characteristics of three street median parks in Malang, which are represent the green street medians in hot humid country of Indonesia. A thermal imaging camera was used to compare the hardscape and softscape surface temperature difference of the three parks. The thermal image results show that stone and paving materials have the highest surface temperatures. Stone as the higher surface temperature is shown in three green streets median. Coral stone has the highest surface temperature at 43.6 °C in Ijen and 42.03 °C in Veteran. Paving also has the highest surface temperature at 43.17 °C in Kunang-kunang. Grass or earth with trees has the lowest surface temperature at 28.53°C in Ijen, 27.93 °C in Kunang-kunang, and 29.17°C in Veteran Street median park. The difference in daytime surface temperature between hardscape and softscape reaches 12.86 °C in Veteran, 15.07 °C in Ijen, 15.24 °C in Kunang-kunang.

Introduction

Urban regions typically have greater surface temperatures than rural areas, as indicated by the terms canopy layer urban heat island (CLUHI) and surface urban heat island (SUHI) (R. Yao et al. 2021). Green and gray infrastructure can affect urban heat island, thermal comfort, and building energy use (Chui et al. 2018). Urban heat islands (UHIs) significantly alter the local microclimate, the temperature conditions close to buildings and their surfaces, and, most crucially, the amount of energy needed to cool down buildings (Enteria, Matteos Santamouris, and Ursula Eicker 2021). Urban green infrastructures (UGIs), such as woods, parks, street trees, private gardens, and vegetated building envelope can help reduce urban air temperatures (Beele et al. 2024).

The global urban population explosion has resulted in a substantial increase in anthropogenic activities and the substitution of vegetation with impervious pavements that possess a high thermal inertia and a dark surface, which has contributed to the UHIs (Seifeddine et al. 2023). Material alterations have a more significant impact on SUHI than vegetation. Although the material's albedo substantially impacts heat islands, the vegetation can affect thermal comfort, and trees can also moderate the cool conditions of the night (Karimi et al. 2020). According to their results, combining low-albedo pavements with trees with

wide crowns and long trunks can provide the best settings for thermal comfort. The existence of green open spaces provides various advantages for conditioning the region's microclimate (Qiu et al. 2017; L. Yao et al. 2020; Stewart and Gerald Mills 2021; Shareef 2022; An et al. 2022). Determine the suitable tree species and green space arrangement can improve the thermal comfort (Feng et al. 2024). One of the thermal characteristics can be shown through the surface temperature of the material (Lee et al. 2018). Surface temperatures are affected by some properties such as geometric, radiative, thermal, moisture, and aerodynamic properties (Oke et al. 2016). Thermal infrared cameras were used to identify the surface temperature of outdoor elements such as building surfaces and infrastructures (Chen et al. 2021), plants and artificial materials under shaded and unshaded conditions (Tan et al. 2021), and urban micro-environments (Feng et al. 2022). As one of the green open spaces, the street trees are the most efficient mitigating feature for lowering surface temperatures of the region's microclimate (Martin, Ramani, and Miller 2024; Lee et al. 2018; L. Yao et al. 2020).

This paper analyzes the thermal characteristics of three street median parks in the hot-humid city of Malang, Indonesia, where in the major cities of Indonesia, the street median park has become one of the forms of urban greening strategies that can help cool the city. The three green streets' medians to be studied have different tropical vegetation and surface covering material characteristics, so it's interesting to know how much surface temperature difference occurs between each material. Using a heat imaging camera, the three green streets' medians were compared with their hardscape and softscape surface temperatures to know the effect of the material and type of vegetation on environmental thermal performance. This study is expected to help choose the type and configuration of material and vegetation, where green open spaces play an important role in reducing UHI in hot humid area.

Methods

Three green streets median Veteran Street, Kunang-kunang, and Idjen Boulevard (Ijen Street median park), located in the Lowokwaru district of Malang City, East Java, Indonesia; were selected as study areas (figure 1). Veteran Street median park surrounded by schools, universities, and trade buildings like shopping malls, cafes, and restaurants. On a 12-meter-wide road edge, Veteran Street median park is 1280m long and 10m broad. This park contains hardscape in crossing areas and plazas, softscape in the shape of shrubs and Trembesi trees far apart but shady due to the large tree canopy. Kunang-kunang street median park in Jakarta Road has similar regional qualities to Veteran Street median park surrounded by education and trade buildings. The 820m-long, 12-meter-wide Kunang-kunang Street median park is on a 10-meter-wide road edge. This park contains hardscape in plazas and softscape on grass with tightly spaced Podocarpus trees, making it very shady. Ijen Street median park is one of Malang City landmarks surrounded by historical residential buildings and some public services including the city library and museum. Ijen Street median park extends 860m and is 15m wide, with 8m roads and a variety of ground cover, including hardscape in the central sitting area, softscape in the form of grass and shrubs, and sparse palm trees.

Figure 1. The case studies

The HTI Ht-A1 infrared camera measures surface temperature and captures real-time thermal images. Target object temperatures for urban surface temperatures are rapidly and accurately measured using the center point measuring cursor (figure 2). The camera has a visible light camera for distinction. The radiation

coefficient can be modified to increase measurement accuracy of half-reflective objects, and the highest and lowest temperature cursor guides users to thermal images' highest and lowest temperatures. Frontal and side thermal pictures offered more accurate data due to site characteristics.

Field measurements were taken in 3 sunny days. Measurements were taken from sunrise to sunset at 6 a.m., 8 a.m., 10 a.m., 12 a.m., 2 p.m., 4 p.m., and 6 p.m. Thus, sun impact average measurements were used to study the green open space surface temperatures throughout those periods. Each measurement zone of the street median park was captured, including hardscape and softscape materials. To get more precise surface temperatures of the measuring zone, the heat thermal imaging camera was simultaneously employed to gather thermal images at a short distance from the middle angle or side angle, depending on site conditions. Figure 3 show the surface temperature of six measuring zones. The zones were chosen because they represent the main thermal comfort characteristics of the street median park. In this quantitative study, the results of the thermal imaging of each zone in the three street median parks were compared to their thermal characteristics, how far the surface temperature differences affected by the different type and configuration of vegetation and surface material.

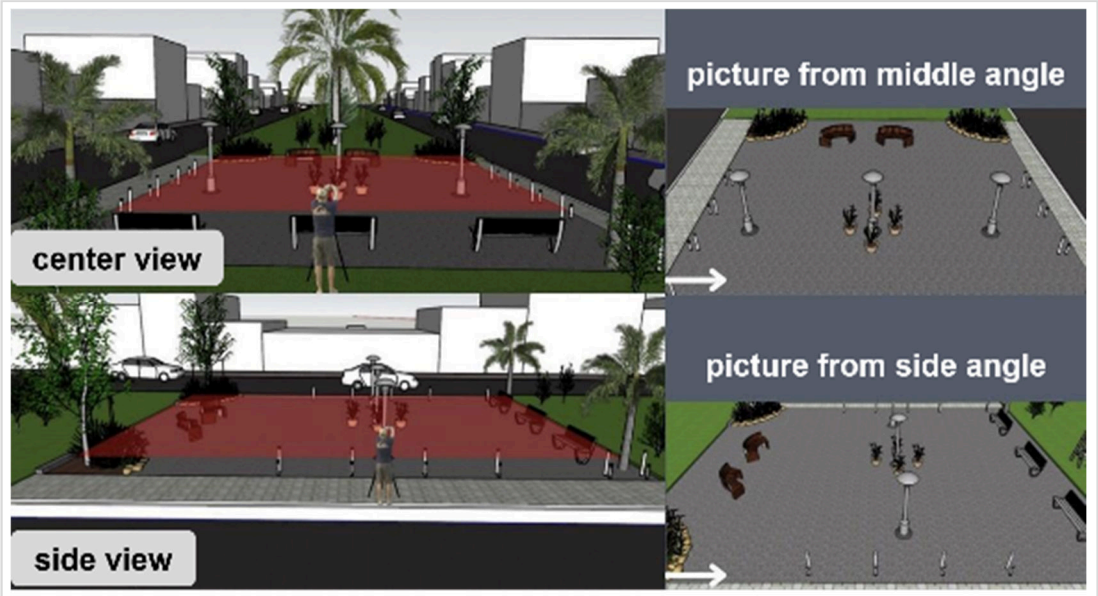

Figure 2. An example of image capturing techniques with thermal imaging camera

Results and discussion

Comparative analysis of the three street median parks

The three street median parks observed have the same characteristics, namely a street boulevard equipped with green areas, pavements, and areas for sitting and relaxing while enjoying the city atmosphere. These three street median parks have different landscaping conditions in terms of ground cover materials such as softscape and hardscape elements and configuration.

Table 1 shows the average surface temperatures of six different measuring zones on each street median park in 3 days. The highest surface temperature was mainly observed in the zone with less softscape materials. Conversely, the zone featuring softscape materials such as grass, shrubs, or trees had the lowest temperature. The lower surface temperature is attributed to the ground cover materials. In comparing the average daytime temperatures of the three street median parks, the lowest average surface temperature was measured on the Veteran Street median park (24,65 °C), where most parts of the green street were fully covered with the shadows of big trees. The surface temperature of Kunang-kunang (26.33 °C), where the street median park coexists

with big amounts of trees, was between the surface temperature of the Veteran and Ijen Street median park. The highest surface temperature was measured on the Ijen Street median park (32.41 °C), due to a lack of trees that could release significant amounts of heat during the day.

Table 1. Average surface temperature of each measuring zones

Street Median Park Zones	1st	2nd	3rd	4th	5th	6th
Veteran	29,47	25,82	24,65	27,31	25,83	26,16
Kunang-kunang	26,64	26,56	26,33	25,71	27,88	31,96
Ijen	32,41	30,99	29,83	26,78	26,03	24,63

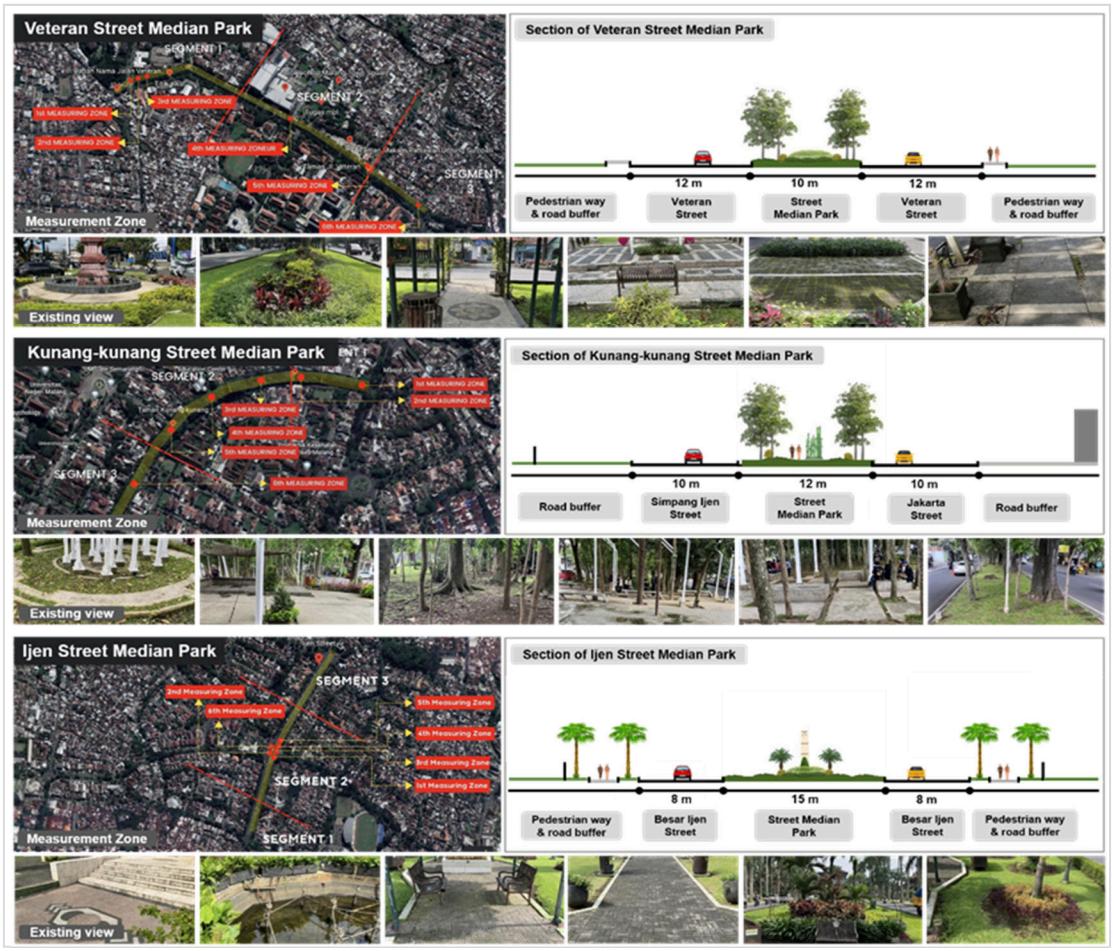

Figure 3. The field measurement zones and section of Veteran, Kunang-kunang, and Ijen Street median park

Analysis of surface temperature on Veteran Street median park

Surface temperatures were measured on Veteran Street median park in comparison to the surface temperatures of Kunang-kunang and Ijen Street median park. This park has a variety of ground cover in the form of hardscape in crossing areas and relaxing sitting areas such as plazas, softscape in the form of shrubs and Trembesi trees arranged quite apart from each other but still quite shady because the tree canopy is wide enough.

A total of thirty-five thermal images were captured to comprehensively encompass the entire study area, spanning a length of 1280 meters. The study area was divided into six different zones as units of analysis to enhance our comprehension of the thermal environments. The 6th zone was observed to be the hottest, and

sample images of the 6th zone are shown in figure 4. Coral stone, andesite stone, and grass were the main materials used in Veteran. Other than that, paving, shrubs, trees, and ponds were used. The average surface temperature in Veteran was 26.54 °C. The condition of each material in Veteran Boulevard is shown in figure 4 with coral stone at the average highest surface temperature of 42.03 °C and grass at the average lowest surface temperature of 29.17°C at the daytime. According to the comparison of surface temperature in Veteran Street median park in figure 5, there are coral stone, andesite stone, and pave stone at the highest temperature while grass and shrubs at the lowest temperature.

Analysis of surface temperature on Kunang-kunang Street median park

Kunang-kunang Street median park has a variety of ground cover in the form of hardscape in relaxing sitting areas such as plazas, softscape in the form of grass equipped with Podocarpus trees with densely spaced distances, and quite a lot so that it tends to be very shady.

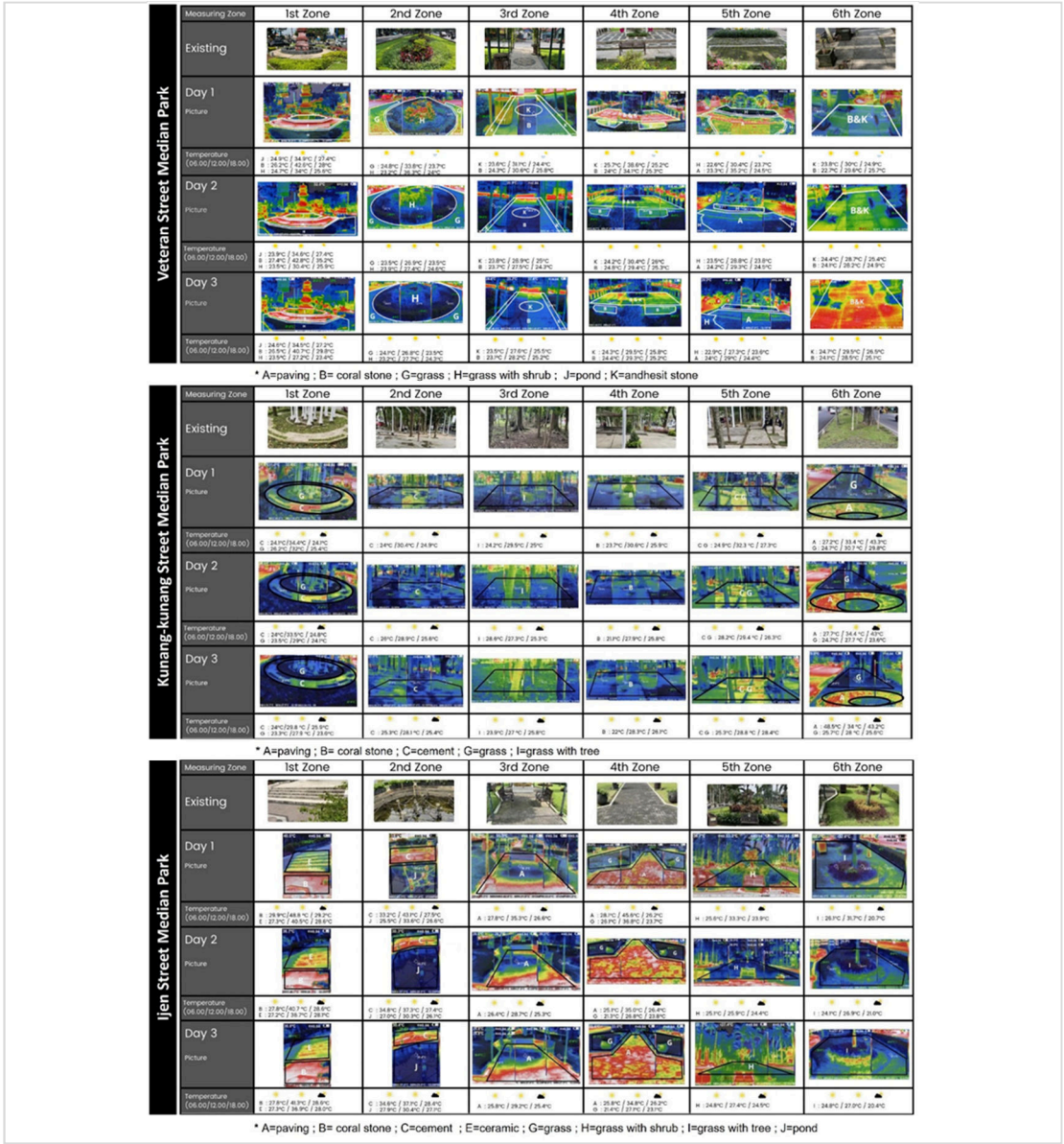

Figure 4. The surface temperature of measurement area using thermal imaging camera

Thirty-five thermal images were taken to fully cover the study area, which is 820 m long. The area of study was divided into 6 different zones as units of analysis to facilitate our understanding of the thermal environments. The 6th zone was observed to be the hottest, and sample images of the 6th zone are shown in figure 4. Cement and grass were the main materials used in Kunang-kunang. Other than that, paving and coral stone were used. The average surface temperature in Kunang-kunang was 27.51 °C. The condition of each material in Kunang-kunang Boulevard are shown in the Figure 4 with paving at the average highest surface temperature at 43.17 °C and grass/earth with big trees as the average lowest surface temperature of 27.93 °C at the daytime. According to the comparison of surface temperature in Kunang-kunang Street median park in Figure 5, there are pave stone and cement plaster as the highest temperature while grass and earth with big trees provide the lowest temperature.

Analysis of surface temperature on Ijen Street median park

Ijen Street median park has a variety of ground cover in the form of hardscape in the relaxing sitting area in the center of the park, softscape in the form of grass and shrubs and sparse palm trees so that conditions in this park are less shady.

The entire 860m-long research area was covered with 35 thermal pictures. To better comprehend the temperature conditions, the research area was also partitioned into six distinct zones to serve as analytical units. The first zone was observed to be the hottest, and sample images of the first zone are shown in figure 4. Paving and grass were the main materials used in Ijen. Other than that, ceramic and ponds were used. The average surface temperature in Ijen was 28.44 °C. The condition of each material in Idjen Boulevard is shown in the figure 4 with coral stone as the highest average surface temperature at 43.6 °C and grass with tree as the average lowest surface temperature at 28.53 °C at the daytime. According to the comparison of surface temperature in Ijen Street median park in figure 5, there are pave stone, coral stone, and cement plaster as the highest temperature while grass with big trees and shrubs has the lowest temperature.

Surface temperature performance on the three street median parks

Figure 4 displays thermal characteristics of green open spaces observed from the highest and lowest surface temperatures to examine the effects of each material on the thermal conditions of each street median park. The zone that was covered by grass and trees had the dominant influence on surface temperatures, where the smallest radiant exitance is shown by the trees and shrubs that act like conduction to the atmosphere and maintain a temperature close to ambient (Loveday et al. 2017). Properly placing trees along the green street area will allow them to shade the ground and reduce surface temperatures by obstructing the sun's rays during the day (Lee et al. 2018). The cooling effect of vegetation on air temperature and urban heat island can always be seen because it is determined by inherent differences in the underlying surfaces, such as albedo, heat absorption and storage, evapotranspiration, and so on (Qiu et al. 2017). The high temperatures are dominant with stone and paving materials in 3 different places. This is proven by the results that show the surface materials and vegetation influencing street median park surface temperatures in table 2.

Orientation and exposure to the sky and light are two examples of the geometric features that impact surface temperatures; the capacity to reflect both shortwave and longwave radiation, as well as to emit the former, is governed by the radiative characteristics; thermal characteristics include heat capacity and thermal conductivity; hydrologic features include the capacity of soil and plant water to evaporate from the surface and near the surface; and aerodynamic properties include length of roughness and protection from wind (Oke et al. 2016). Overall, the average surface temperature of the three street median parks was 26.54 °C in Veteran, 27.51 °C in Kunang-kunang, and 28.44 °C in Ijen street median park. The results showed that the presence of large trees that covered the surface of the soil or grass was able to give lower surface temperatures because it prevented exposure to sunlight in Veteran and Kunang-kunang street gardens, where Ijen showed higher average surface temperature due to not much shadow by the large tree.

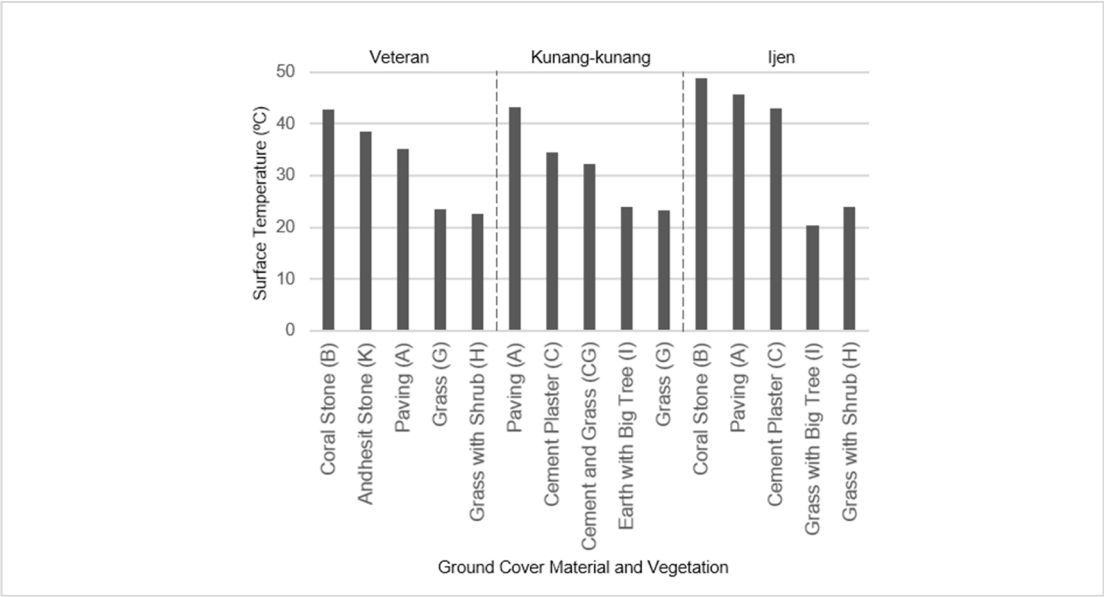

Figure 5. Each ground cover materials and vegetation surface temperature

Table 2. Surface materials and vegetation influencing street median park surface temperatures

Street Median Park	High Surface Temperature			Low Surface Temperature	
	1st	2nd	3rd	1st	2nd
Veteran	Coral stone (B)	Andesite stone (K)	Paving (A)	Grass (G)	Grass with shrub (H)
Kunang-kunang	Paving (A)	Cement plaster (C)	Cement and grass (CG)	Earth with big tree (I)	Grass (G)
Ijen	Coral stone (B)	Paving (A)	Cement plaster (C)	Grass with tree (I)	Grass with shrub (H)

It is proven that the thermal performance of materials is determined by their surface temperature and emittance, which causes radioactive cooling and determines how much thermal radiation they radiate into the environment. The cooling impacts of tree cover were more significant than those of vegetation cover (Smith, Fabian, and Hutyra 2023). The influence of the albedo on thermal comfort is not as significant than the tree cover (Mohammad et al. 2021).

Conclusions

This study examined the thermal properties of three distinct street median parks by utilizing thermal imaging cameras in hot humid city. The three parks studied represented the street median parks in Indonesian hot humid urban areas, characterized using hardscape materials such as paving and coral stone, as well as softscape forms of grass either without or with shrubs or trees. Results showed that grass with trees significantly reduce daytime surface temperatures due to their shading and cooling effects. However, stone and paving materials have higher surface temperatures than the natural vegetation with surface temperature difference reached 15.24 °C at the daytime. It happened because of the physical characteristics of the stone and paving materials that have different albedo, colour, the surface texture, and the construction material.

Selection of the hardscape and softscape materials in the street median park like the use of "cold" materials, big trees, shrubs, adding shade to the pavement material, and other similar things is important in enhancing microclimate conditions especially in hot humid cities. Choosing the right hardscape and softscape materials that contributes to the reducing the surface temperature can be one of the UHI mitigation strategies.

Acknowledgments

The authors extend their gratitude to Universitas Brawijaya for the support of this research.

References

An, Hongmin, Hongyan Cai, Xinliang Xu, Zhi Qiao, and Dongrui Han. 2022. "Impacts of Urban Green Space on Land Surface Temperature from Urban Block Perspectives." *Remote Sensing* 14 (18): 4580. https://doi.org/10.3390/rs14184580.

Beele, Eva, Raf Aerts, Maarten Reyniers, and Ben Somers. 2024. "Spatial Configuration of Green Space Matters: Associations between Urban Land Cover and Air Temperature." *Landscape and Urban Planning* 249 (September):105121. https://doi.org/10.1016/j.landurbplan.2024.105121.

Chen, Ling, Yuhong Wang, Siqi Jia, and Ming-Fung Francis Siu. 2021. "Development of Panoramic Infrared Images for Surface Temperature Analysis of Buildings and Infrastructures." *Energy and Buildings* 232 (February):110660. https://doi.org/10.1016/j.enbuild.2020.110660.

Chui, Andrew C., Alexei Gittelson, Elizabeth Sebastian, Natasha Stamler, and Stuart R. Gaffin. 2018. "Urban Heat Islands and Cooler Infrastructure – Measuring near-Surface Temperatures with Hand-Held Infrared Cameras." *Urban Climate* 24 (June):51–62. https://doi.org/10.1016/j.uclim.2017.12.009.

Enteria, Napoleon, Matteos Santamouris, and Ursula Eicker. 2021. *Urban Heat Island (UHI) Mitigation*. Singapore: Springer Nature.

Feng, Li, Yanxia Liu, Yanan Zhou, and Shaoqi Yang. 2022. "A UAV-Derived Thermal Infrared Remote Sensing Three-Temperature Model and Estimation of Various Vegetation Evapotranspiration in Urban Micro-Environments." *Urban Forestry & Urban Greening* 69 (March):127495. https://doi.org/10.1016/j.ufug.2022.127495.

Feng, Li, Linru Shuai, Yanan Zhou, Xiao Zhang, and Jiaxin Sun. 2024. "Improving the Green Space Arrangement in Residential Areas from the Perspective of Tree Leaf Temperature Utilizing Scenario Simulation in ENVI-Met." *Science of The Total Environment* 918 (March):170650. https://doi.org/10.1016/j.scitotenv.2024.170650.

Karimi, Alireza, Hanyieh Sanaieian, Hamed Farhadi, and Saeid Norouzian-Maleki. 2020. "Evaluation of the Thermal Indices and Thermal Comfort Improvement by Different Vegetation Species and Materials in a Medium-Sized Urban Park." *Energy Reports* 6 (November):1670–84. https://doi.org/10.1016/j.egyr.2020.06.015.

Lee, Sugie, Hyunbin Moon, Yeri Choi, and D. K. Yoon. 2018. "Analyzing Thermal Characteristics of Urban Streets Using a Thermal Imaging Camera: A Case Study on Commercial Streets in Seoul, Korea." *Sustainability* 10 (2): 519. https://doi.org/10.3390/su10020519.

Loveday, Jane, Grant Loveday, Josh Byrne, Boon-lay Ong, and Peter Newman. 2017. "Quantifying Radiation from Thermal Imaging of Residential Landscape Elements." *Renewable Energy and Environmental Sustainability* 2 (August):17. https://doi.org/10.1051/rees/2017041.

Martin, Miguel, Vasantha Ramani, and Clayton Miller. 2024. "InfraRed Investigation in Singapore (IRIS) Observatory: Urban Heat Island Contributors and Mitigators Analysis Using Neighborhood-Scale Thermal Imaging." *Energy and Buildings* 307 (March):113973. https://doi.org/10.1016/j.enbuild.2024.113973.

Mohammad, Pir, Soheila Aghlmand, Ashkan Fadaei, Sadaf Gachkar, Darya Gachkar, and Alireza Karimi. 2021. "Evaluating the Role of the Albedo of Material and Vegetation Scenarios along the Urban Street Canyon for Improving Pedestrian Thermal Comfort Outdoors." *Urban Climate* 40 (December):100993. https://doi.org/10.1016/j.uclim.2021.100993.

Oke, T. R., G. Mills, A. Christen, and J. A. Voogt. 2016. "Urban Climates." In *Microclimate and Local Climate*, 243–60. Cambridge University Press. https://doi.org/10.1017/CBO9781316535981.013.

Qiu, Guo Yu, Zhendong Zou, Xiangze Li, Hongyong Li, Qiuping Guo, Chunhua Yan, and Shenglin Tan. 2017. "Experimental

Studies on the Effects of Green Space and Evapotranspiration on Urban Heat Island in a Subtropical Megacity in China." *Habitat International* 68 (October):30–42. https://doi.org/10.1016/j.habitatint.2017.07.009.

Seifeddine, Khaled, Sofiane Amziane, Evelyne Toussaint, and Salah-Eddine Ouldboukhitine. 2023. "Review on Thermal Behavior of Cool Pavements." *Urban Climate* 51 (September):101667. https://doi.org/10.1016/j.uclim.2023.101667.

Shareef, Sundus. 2022. "The Influence of Greenery and Landscape Design on Solar Radiation and UHI Mitigation: A Case Study of a Boulevard in a Hot Climate." *World* 3 (2): 175–205. https://doi.org/10.3390/world3020010.

Smith, Ian A., M. Patricia Fabian, and Lucy R. Hutyra. 2023. "Urban Green Space and Albedo Impacts on Surface Temperature across Seven United States Cities." *Science of The Total Environment* 857 (January):159663. https://doi.org/10.1016/j.scitotenv.2022.159663.

Stewart, Iain D., and Gerald Mills. 2021. *The Urban Heat Island*. 1st ed. Cambridge: ELSEVIER.

Tan, J.K.N., R.N. Belcher, H.T.W. Tan, S. Menz, and T. Schroepfer. 2021. "The Urban Heat Island Mitigation Potential of Vegetation Depends on Local Surface Type and Shade." *Urban Forestry & Urban Greening* 62 (July):127128. https://doi.org/10.1016/j.ufug.2021.127128.

Yao, Lei, Tong Li, Mingxue Xu, and Ying Xu. 2020. "How the Landscape Features of Urban Green Space Impact Seasonal Land Surface Temperatures at a City-Block-Scale: An Urban Heat Island Study in Beijing, China." *Urban Forestry & Urban Greening* 52 (June):126704. https://doi.org/10.1016/j.ufug.2020.126704

Yao, Rui, Lunche Wang, Xin Huang, Yuting Liu, Zigeng Niu, Shaoqiang Wang, and Lizhe Wang. 2021. "Long-Term Trends of Surface and Canopy Layer Urban Heat Island Intensity in 272 Cities in the Mainland of China." *Science of The Total Environment* 772 (June):145607. https://doi.org/10.1016/j.scitotenv.2021.145607.

Author(s) contribution

Wasiska Iyati contributed to the research plan preparation, methodologies, literature review, visualization, data analysis, article drafting and revisions.

Ayu Nur Izzati Hilmy contributed to the field measurement, data analysis, article drafting, and visualization.

Rika Nur Fitriani contributed to the field measurement, data analysis, article drafting, and visualization.

Alya Nafisa Fidelista contributed to the field measurement, data analysis, article drafting, and visualization.

Jono Wardoyo contributed to the methodologies and field measurement preparation.

This page is intentionally left blank