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The relationship between the cooling effect of parks and the urban heat island effect in Jakarta and Bandung

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Abstract. Cities around the world are experiencing the Urban Heat Island phenomenon, due to increasing urbanization and human activity, as well as environmental degradation characterized by a lack of green space. With the remaining green open spaces in urban areas, what contribution can they make to address this phenomenon? According to several journals, green open spaces can provide cooling effects through trees, and when combined with blue spaces such as water, the results can be optimized. Therefore, the objective of this study is to examine whether there is a connection between the cooling effects of parks in two cities (Jakarta and Bandung) and surface land temperatures, one of the ways to observe the Urban Heat Island phenomenon. The research method used is quantitative descriptive, with several stages of analysis, including LST analysis and the cooling effect of parks. The results of this study indicate a connection between the cooling aspects of parks, divided into two character: large parks (area, intensity, gradient) and small parks (efficiency) in relation to surface temperature in the districts where the parks are located.

1 Introduction

Cities generally serve as economic hubs, attracting people from surrounding areas to work and live close to their activities. This phenomenon occurs worldwide, indicating population density in urban areas. According to UN projections, 70% of the world's population will live in urban areas by 2050 [1]. As a result, population growth is accompanied by an increase in various facilities and supporting infrastructure, serving as one of the indicators of the region's growth [2, 3]. This, in turn, leads to significant changes in land use to support the concentrated activities of the population [4]. These massive and uncontrolled changes in land use, such as the construction of buildings and infrastructure converting open and vegetated

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spaces whether caused by residents or regional policy directions impact environmental degradation, leading to climate change in the area [1, 5].

The climate change caused by this urbanization process makes urban areas hotter than surrounding areas, a phenomenon known as the Urban Heat Island effect, which directly and indirectly impacts air quality and the living environment [6]. According to Aghamohammadi et al. [7], the Urban Heat Island (UHI) is a heat phenomenon caused by increased urbanization and reduced vegetation cover, open burning, traffic, land use changes, etc. Similarly, Kotecha et al. [8] mention that the heat island phenomenon is caused by anthropogenic activities, industrialization, etc. Another opinion states that urbanization, which alters land cover, leads to increased temperatures and exacerbates the Urban Heat Island effect [9]. A similar scenario is outlined in the International Panel on Climate Change (IPCC) climate change projections, which predict a temperature increase of 4°C in Southeast Asian cities by 2050 [7].

The effects of the urban heat island phenomenon are predicted to be dangerous and will increase with global warming. The consequences of the Urban Heat Island phenomenon, which are generally easy to feel, cause discomfort, but will also have an impact on the health and economy of cities and the activities of their residents. Examples of health threats resulting from this phenomenon include reduced comfort when engaging in outdoor activities, heat exhaustion, heat cramps, respiratory illnesses among tropical city dwellers, and a high risk of mortality [7, 8]. This occurred in East Asia between 2000 and 2019, resulting in over 101,000 deaths, or approximately 20% of the total mortality rate in that region. Therefore, this issue has become a global concern, as outlined in the Sustainable Development Goals (SDGs), specifically in Goal 11, which aims to make cities and settlements resilient and sustainable, intersecting with Goals 3, 7, and 13 [10].

Research on the urban heat island phenomenon in Indonesian cities has shown that increased land use and human activities lead to warming in city centers and primary collector roads. Controlling this phenomenon involves providing green open spaces that incorporate environmentally friendly concepts [11]. According to Larasati et al. [12], the pattern of the Urban Heat Island phenomenon is formed based on urban activities that impact land use changes into residential, office, commercial, and industrial areas, while land uses such as water bodies and green open spaces have lower temperature values. Specifically, the contribution to the Urban Heat Island phenomenon is due to residential land use [12]. Researchers studying slum areas in relation to this phenomenon note that the configuration of buildings and land use are key factors in the increase of the Urban Heat Island effect in unplanned and slum residential areas, due to the lack of vegetation, obstructed airflow, and the impaired function of water bodies contaminated by domestic waste. Therefore, strategies such as restoring the function of water bodies and redeveloping the area are necessary.

Green infrastructure is a concept or approach to protecting the environment by implementing green open space planning and maintaining natural processes or cycles. In principle, the application of green infrastructure or environmentally friendly infrastructure aims to reduce resource use, promote resource recycling to preserve nature, and mitigate climate change and disasters. According to Pritipadmaja et al. [13], there is potential for blue-green infrastructure to mitigate or reduce the effects of urban heat islands, thereby cooling the urban environment in a more sustainable manner by implementing several strategies, including increasing green space coverage and optimizing access to water bodies [13]. Another opinion reinforces this by finding that the application of green-blue infrastructure has high value in cooling water areas and dense vegetation in terms of the heat mitigation index [14]. Meanwhile, other researchers argue that this infrastructure can optimally cool cities ideally, depending on time, materials, and water temperature [15].

Essentially, urban parks as part of the green-blue infrastructure of urban ecosystems have lower temperatures, providing greater comfort in outdoor spaces compared to surrounding urban areas dominated by impermeable surfaces [16, 17]. Urban parks containing landscape components such as water bodies, soil, and various vegetation (providing evaporation and cooling effects) can create a park cooling effect [18]. Wang et al. [19] reported that park areas ranging from 1.34 ha to 17 ha exhibit the best park cooling island effect, with factors such as park shape, tree density, water coverage, and impervious surfaces showing positive correlations. Another opinion based on their research states that the matrix or layout of vegetation is an important indicator of park cooling efficiency [20]. The cooling effect in Dutch parks is 4°C lower than the surrounding areas [21]. A study in Nanyang on 30 parks found that they could cool the Land Surface Temperature (LST) by more than 1°C [22]. According to Gill et al. [23], vegetation plays a role in creating extensive shaded areas, preventing direct solar heat radiation, and providing cooler conditions in urban climates [23].

The cities studied by Saringatin et al. [24] across 10 regions in Java from 2015 to 2019 revealed that, based on the trends analyzed, there was significant heat stress according to the PET criteria, affecting cities such as Jakarta, Bandung, and Surabaya. In another study of three urban areas over two decades, the increase in surface temperature within the urban heat island varied as follows: 1) Jabodetabek from 2.46°C to 5.97°C; 2) Bandung-Cimahi with a value of 1.55°C to 5.54°C; and 3) Sukabumi with a value of 0.56°C to 3.76°C [25]. According to a CNN report, the Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG) revealed that the urban heat island phenomenon in several cities over the past 30 years has caused a 20% increase in cities in Indonesia based on land surface temperature (LST) values, due to water-impermeable surfaces and reduced vegetation [26]. The condition of Green Open Spaces (GOS) in Jakarta (9.12% or 2,748.81 hectares) and Bandung City (12.25% or 2,048.97 hectares) remains below the national standard set by Law No. 26 of 2007 [27]. Therefore, the objective of this study is to analyze the relationship between the cooling effect of parks and the Urban Heat Island (UHI) phenomenon in the affected districts of Jakarta and Bandung, to understand the role of parks in both cities in addressing the UHI phenomenon.

2 Methods

The research locations were selected parks in the two cities of Jakarta and Bandung. The selection of these parks was based on several criteria, including: 1) located in districts with very high impact in the land surface temperature (LST) category for 2025; 2) the park is a public space; 3) the typology of urban parks and/or district parks; and 4) having two characteristics (more than 1 ha and less than 1 ha).

The research approach used a quantitative descriptive method. Quantitative research focuses on measuring and analyzing relationships between various variables [28]. According to Sugiyono, the descriptive approach is used to explain data descriptions or analysis results without drawing general conclusions.

Thus, the data requirements for this study are secondary, including Landsat 8 OLI/TIRS satellite imagery from 2025 to obtain Land Surface Temperature values, which are one way to observe the Urban Heat Island and parks in the study area through Google Earth, digitized using the ArcGIS 10.8 application. Therefore, several steps are required, including: 1) The first stage involves analyzing Land Surface Temperature (LST) using satellite band 10, along with bands 4 and 5 for green areas, known as the Normalized Difference Vegetation Index (NDVI), to obtain values that describe the Urban Heat Island (UHI) phenomenon [29, 30]; 2) The aspects of the park cooling effect variables considered based on research [31, 32] such as Park Cooling Area (PCA), Park Cooling Intensity (PCI), Park Cooling Efficiency (PCE), and Park Cooling Gradient (PCG), with the steps for determining these four aspects following the research [33]. And 3) Third, in determining the relationship between the cooling effect of parks and UHI (as seen from the average values in the selected subdistricts) using multiple linear regression statistical analysis and t-tests, with the process conducted through the SPSS application [34]. In this multiple linear regression analysis, the cooling effect of parks, which includes the four aspects, serves as the independent variable, while the dependent variable in this study is the Urban Heat Island.

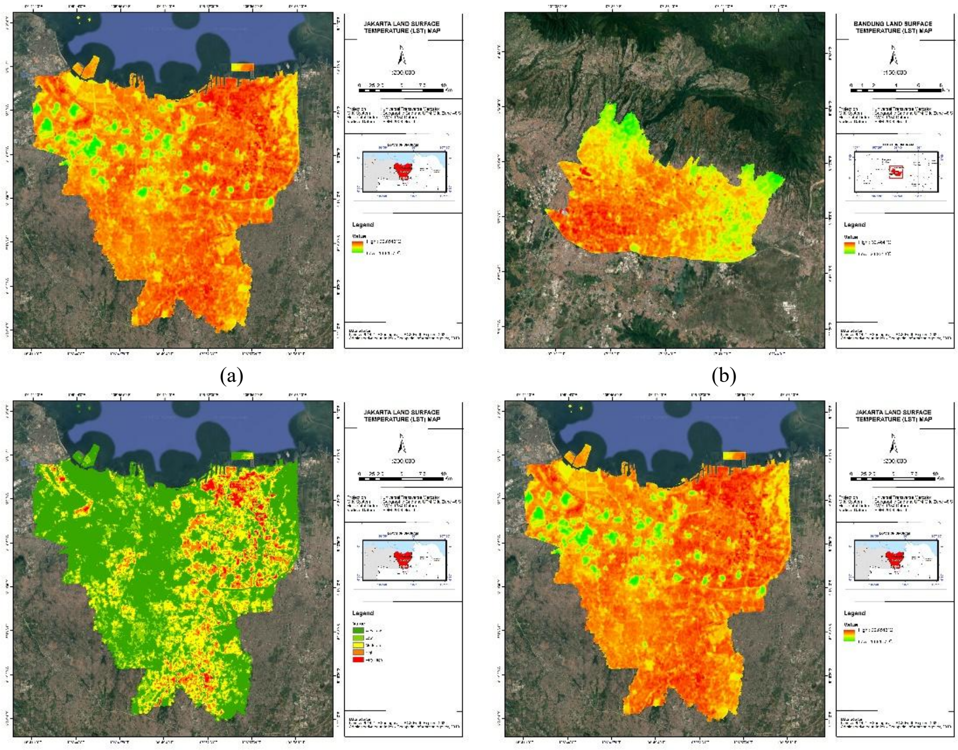
Table 1. Classification of land surface temperature.

Classification	**Value Range (°C)**
Very Low	< 26,49
Low	26,49-27,31
Moderate	27,31-28,31
High	28,31-29,14
Very High	>29,14

3 Results and discussion

3.1 Land surface temperature distribution

This analysis process based on satellite imagery depicts the distribution of land surface temperatures in observing the Urban Heat Island phenomenon. It was found that districts affected by this phenomenon with a very high classification had differences in area values between the two locations. In Bandung, approximately 50% of the district's area was affected, while in Jakarta, the affected districts covered less than 50% of the area, with an average area of 8.61% of the district's territory. Considering parks with the specified criteria as research objects, the districts selected in the two regions are: 1) Bandung, with two districts (Regol and Sumur Bandung); and 2) Jakarta, comprising Tanjung Priok District, Cilincing District, Cakung District, and Ciracas District.



(a) (b) (c) (d)

Fig. 1. LST results (a & b) and reclassification (c & d) in Jakarta and Bandung.

Table 2. Distribution of subdistricts in the research area based on land surface temperature analysis results.

City	District	Average temperature
Bandung	Regol	29,65°C
	Sumur Bandung	29,13°C
Jakarta	Tanjung Priok	27,08°C
	Cilincing	25,16 °C
	Cakung	27,16 °C
	Ciracas	27,57 °C

Table 2 shows the average land surface temperature (LST) values for certain districts in Bandung and Jakarta. This lets us compare the thermal conditions in the research areas. The results show a clear difference in temperature between the two cities. The chosen districts in Bandung, Regol and Sumur Bandung, have high LST values, with averages of 29.65°C and 29.13°C, respectively. These temperatures support the earlier classification results, showing that a large part of Bandung's urbanized areas is in the "very high" Urban Heat Island (UHI) category.

The districts chosen in Jakarta, on the other hand, have lower average LST values. The average temperature in Tanjung Priok, Cakung, and Ciracas is between 27.08°C and 27.57°C, while Cilincing has the lowest average at 25.16°C. These differences are in line with the earlier finding that the UHI-affected areas in Jakarta make up a smaller part of the total district area, averaging only 8.61%. This indicates that, notwithstanding Jakarta's significant urban development, the spatial intensity of UHI is more concentrated compared to Bandung.

There could be a lot of things that affect the temperature difference between Bandung and Jakarta. Bandung's geography, which is mostly in a basin, along with the fact that it has a lot of built-up land cover, may cause heat to stay in the area and slow down the flow of air, which would raise surface temperatures. On the other hand, the chosen areas in Jakarta include coastal and industrial zones, where different types of land cover, open spaces, and coastal airflow may help cool down the surface, leading to a wider range of temperature changes.

The table confirms the spatial patterns seen in the LST mapping (Fig. 1) and shows how important localized environmental conditions are in determining UHI intensity. These results confirm the appropriateness of the chosen districts as representative locations for evaluating the impact of urban parks on reducing elevated land surface temperatures.

3.2 Cooling effect of parks

The parks that were the subject of this study are located in areas with high concentrations of residential, commercial, and service industries. The parks in Bandung are located in the city center, while those in Jakarta are located in the eastern part of the city (from north to south).

Table 3. Distribution of research object parks based on subdistricts affected by the UHI phenomenon.

City	District	Parks >1 ha	Parks <1 ha
Bandung	Regol	- Taman Tegalega - Taman Alun-Alun Bandung	- Ciateul
	Sumur Bandung	- Taman Balai Kota - Taman Lalu Lintas Kota Bandung	- Taman Anak Tongkeng - Taman Foto Bandung - Taman Viaduct Utara - Taman Vanda - Taman Teras Cikapundung - Taman Musik
Jakarta	Tanjung Priok	- Taman Danau Sunter Selatan - BMW Park	- Taman Segitiga Tanjung Priok
	Cilincing	- Taman Rotan Nusa - Taman Malaka Asri - Taman Ketapang	- Taman Ondel-ondel - Taman Tipar Asri
	Cakung	- Taman Semut JGC	- Taman Kota Garden City
	Ciracas	- Taman Kumis Kucing	- Taman Layangan - Taman Maju Bersama Tulip

To better illustrate the comparison between parks in terms of Land Surface Temperature (LST) values and the buffer zones in both areas, as shown in Figure 1 for large parks covering more than 1 ha and Figure 2 for small parks (< 1 ha). Generally, the farthest cooling area between the park boundary and the outer boundary (buffer zone) as the highest temperature before a decrease occurs is at 540 m. The variation in cooling areas depends on the location, influenced by the surrounding area, including the presence or absence of green corridors or small parks outside the typology of urban parks and district parks in this study.

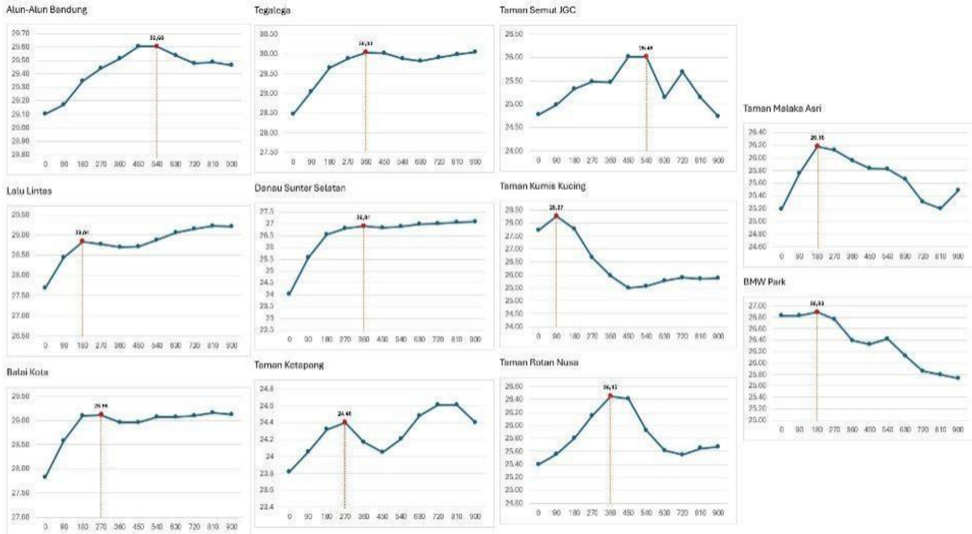


Fig. 2. Large garden plots or > 1ha based on the rate of surface temperature change to the buffer zone or first turning point.

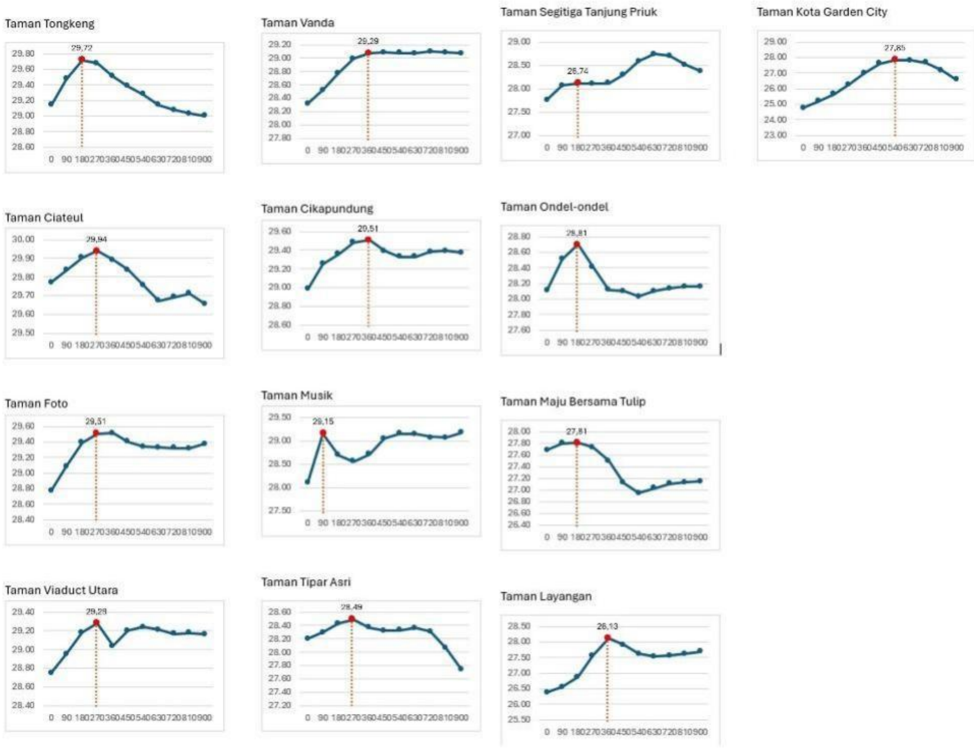


Fig. 3. Graph of several small parks based on the rate of surface temperature values to buffer zones or first turn points.

When comparing surface temperatures in parks with cooling intensity, large parks in Bandung have an average temperature of 3.7°C with stable cooling intensity ranging from 1°C, except for Bandung's alun-alun park, which is affected by building density and limited green areas. Meanwhile, parks with an area of over 1 hectare in Jakarta have an average temperature of around 25°C, due to their location in a low-lying area compared to Bandung. However, the average cooling intensity of large parks (> 1 hectare) in Jakarta, as shown in

Figure 4, is 0.97°C, which is not significantly different from Bandung. Ketapang Park in Jakarta has a low cooling intensity value because the area still has a significant amount of green space, so it does not exhibit a notably different temperature. In addition to Ketapang Park, the highest PCI value among large parks is found in Sunter Selatan Lake Park. This park is influenced not only by the green corridors in the surrounding environment or buffer zones but also by an additional factor the lake resulting in a combination of green and blue spaces. This aligns with the statement that parks around water bodies can effectively form blue-green cooling [17, 22, 35].

The Land Surface Temperature (LST) observed in small parks (< 1 ha) in the two cities averages 28°C, due to satellite imagery capturing a ratio of 1 pixel to 30x30 meters, thereby generalizing the surrounding conditions that tend to absorb heat. However, the cooling intensity of these small parks is around 0.5°C, with the exception of three parks located in areas with abundant surrounding vegetation, such as green belts or green corridors, including Music Park (Bandung), Kite Park (Jakarta), and Garden City Park (Jakarta). According to research in Tangerang, parks with low surface temperatures tend to have larger areas, while smaller parks have higher surface temperatures.

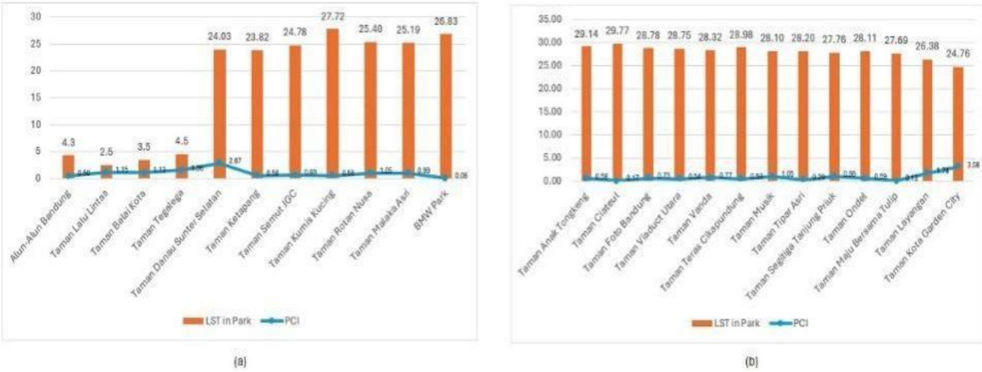


Fig. 4. Graph showing the relationship between temperature in the park and cooling intensity values for two types of parks: (a) large parks and (b) small parks.

Thus, the average cooling effect of parks can be calculated through four aspects: PCA, PCI, PCE, and PCG in large parks (> 1 ha) and small parks (< 1 ha) as shown in Figure 5. The three aspects Park Cooling Gradient, Park Cooling Intensity, and Park Cooling Area show superior values in large parks, due to the influence of large green areas with more mature trees. The results are reversed for other cooling aspects, as the cooling efficiency of small parks contributes more significantly to their smaller coverage area or environment.

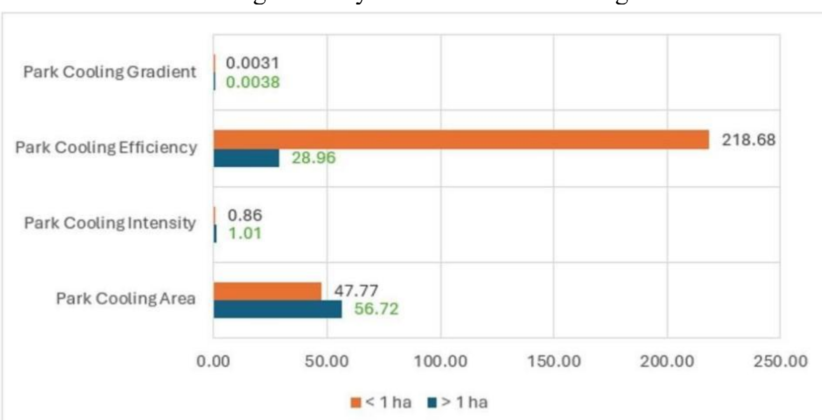


Fig. 5. Comparison of four variables of the cooling effect of parks between large parks (>1 ha) and small parks (<1 ha).

3.3 The relationship between the cooling effect of parks and land surface temperature

In determining the relationship between the independent variable (cooling effect of parks) and the dependent variable (Urban Heat Island), the model constructed based on statistical tests is first examined. The model in question is the R-Square value, which has two distinct values from this study, as shown in Figure 6. The R-Square value in the model summary table can be referred to as the coefficient of determination to assess the extent of the contribution between the independent variables and the dependent variable [36]. Based on this rule, the prediction for large parks is higher at 66.1%, while small parks are only 43.7%.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.813[a]	.661	.435	1.33237	.661	2.926	4	6	.116

a. Predictors: (Constant), Park Cooling Gradient, Park Cooling Area, Park Cooling Efficiency, Park Cooling Intensity

b. Dependent Variable: Land Surface Temperature

(a)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.661[a]	.437	.156	1.41432	.437	1.554	4	8	.276

a. Predictors: (Constant), Park Cooling Gradient, Park Cooling Area, Park Cooling Efficiency, Park Cooling Intensity

b. Dependent Variable: Land Surface Temperature

(b)

Fig. 6. Summary of r square from (a) large park and (b) small park against the dependent variable of land surface temperature.

After obtaining the predictions from the constructed model, a t-test was conducted to examine the variables of the cooling effect of parks that influence or are related to the average temperature of the land surface temperature in the subdistrict. The results of this test are shown in Figure 7. According to Muhid, the determination of the t-test in statistical analysis has the following references: 1) If Thitung > Ttabel, then there is a relationship between the independent variable and the dependent variable; and 2) conversely to point 1, if Thitung < Ttabel, then there is no relationship [36].

Var.	Park > 1 ha			Park < 1 ha		
	Thitung	Ttabel	Status	Thitung	Ttabel	Status
Park Cooling Area	3,275		Correlation	-0,254		No
Park Cooling Intensity	-2,791	2,228	Correlation	-0,265	2,306	No
Park Cooling Efficiency	-1,679		No	2,362		Correlation
Park Cooling Gradient	2,234		Correlation	1,055		No

Fig. 7. T-test tabulation.

Parks with an area of more than 1 ha have a positive relationship with the Park Cooling Area and Park Cooling Gradient variables with the LST value of the subdistrict where the park is located, with the interpretation that the higher the land surface temperature value in that area, the wider the cooling area that can be provided by the park with its unidirectional cooling rate. However, it has a negative relationship with Park Cooling Intensity, meaning that the higher the LST value in the area, the lower the cooling intensity or the smaller the difference in surface temperature between the park and its surrounding area. Conversely, for small parks (<1 ha), there is an influence on the park's cooling efficiency aspect on the dependent variable, meaning that the higher the LST value in the area, the greater the cooling effect produced in the urban micro-area, providing temperature comfort for residents or activities near the small park.

4 Conclusion

This study verified that urban parks significantly reduce land surface temperature (LST) in Jakarta and Bandung, illustrating their role in mitigating the Urban Heat Island (UHI) effect. For large parks, Park Cooling Area (PCA) and Park Cooling Gradient (PCG) were both positively correlated with temperature at the district level. On the other hand, Park Cooling Intensity (PCI) was negatively correlated. Park Cooling Efficiency (PCE) was the main factor influencing how well small parks cooled. These results suggest that park size and the surrounding landscape structure are crucial for how well they cooled. A limitation of this study is that it did not utilize data from relevant government agencies. Future research should investigate additional spatial, morphological, and design elements, supported by simulation-based analysis, to improve UHI mitigation strategies in urban areas in Indonesia.

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