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Utilization of Multitemporal Landsat Images for Analysis Urban Heat Island Based on Google Earth Engine in Cimahi City

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ABSTRACT

Cimahi City is physically part of the Bandung-Cimahi core city conurbation of the system of cities in the Bandung City Basin Region so that it has high development activity. This condition causes an increase in the surface temperature of Cimahi City, especially in the downtown area and triggers the Urban heat island phenomenon. This research was conducted to map multi temporal spatial changes in the vegetation index (MSAVI) and land surface temperature (LST) in Cimahi City in 2015, 2019 and 2023 and to analyze their relationship to the phenomenon and the widespread distribution of urban heat island using Landsat 8 imagery by integrating cloud techniques. computing Google Earth Engine. The results of surface temperature (LST) were correlated with vegetation density (MSAVI) using a simple regression test to determine how much influence changes in vegetation density had on surface temperature (LST). The distribution of urban heat islands was obtained from the classification of LST processing with urban heat island threshold values. The results showed that there was an increase in the distribution area of the urban heat island phenomenon with a total area of urban heat island increasing by 1319.94 Ha in 2015, 3389.04 Ha in 2019, and 3634.04 Ha in 2023. The areas that are dominated by urban impacts The heat island occurred in South Cimahi District with an area affected of 1440.43 Ha.
Keywords: Google Earth Engine, Vegetation Density, Land surface temperature, Urban heat island.

ABSTRAK

Kota Cimahi secara fisik merupakan bagian dari konurbasi kota inti Bandung-Cimahi dari sistem kota-kota di Kawasan Cekungan Kota Bandung sehingga memiliki aktivitas pembangunan yang tinggi. Kondisi ini menyebabkan meningkatnya suhu permukaan Kota Cimahi terutama di daerah pusat kota dan memicu terjadinya fenomena Urban heat island. Penelitian ini dilakukan untuk memetakan perubahan spasial secara multitemporal indeks vegetasi (MSAVI) dan suhu permukaan tanah (LST) di Kota Cimahi tahun 2015, 2019, dan 2023 serta menganalisis keterkaitannya dengan fenomena dan sebaran luas Urban heat island menggunakan citra Landsat 8 dengan mengintegrasikan teknik cloud computing Google Earth Engine. Hasil suhu permukaan (LST) dikorelasikan dengan kerapatan vegetasi (MSAVI) menggunakan uji regresi sederhana untuk mengetahui seberapa besar pengaruh perubahan kerapatan vegetasi terhadap suhu permukaan (LST). Persebaran urban heat island diperoleh dari klasifikasi pengolahan LST dengan nilai ambang batas urban heat island. Hasil penelitian menunjukan terjadi peningkatan luas sebaran fenomena urban heat island dengan luas total peningkatan urban heat island sebesar 1319,94 Ha di tahun 2015, 3389,04 Ha di tahun 2019, dan 3634,04 Ha di tahun 2023. Daerah yang mendominasi terkena dampak urban heat island terjadi di Kecamatan Cimahi Selatan dengan luas wilayah yang terdampak seluas 1440.43 Ha.
Kata kunci: Google Earth Engine, Kerapatan Vegetasi, Land surface temperature, Urban heat island.

1. INTRODUCTION

Cimahi City is physically part of the Bandung – Cimahi core city conurbation from the system of cities in the Bandung Basin Area. Based on data obtained from the Central Statistics Agency of Cimahi City, currently, the number of people living in Cimahi City is 575,235 people which is certainly not proportional to the area of Cimahi City which is only 40.2 km2 or 4020 ha (Badan Pusat Statistik, 2022). In addition, most of the administrative areas in Cimahi City are already built-up areas. In Cimahi City, the built-up area has reached 61.55% of the total area.

This causes an imbalance between the built-up area and green open areas. The existence of development with the conversion of land functions, especially vegetation into built-up land along with an increase in population and urbanization can increase the temperature in urban areas. The dominance of artificial materials that accommodate heat (heat storage) in urban areas will increase the temperature of the earth's surface. The materials used in building buildings absorb radiant heat from the sun and radiate it back to the surroundings, thereby increasing the surrounding temperature (Feizizadeh & Blaschke, 2013; Mallick et al., 2013; Syuhada & Suhaeri, 2010).

Built-up areas that continue to grow but are not accompanied by an increase in the amount of carbon dioxide absorbing vegetation (CO_2) resulted in temperature conditions in the City of Cimahi increasing and feeling hotter. In addition, the reduction in green open land due to land conversion is one of the causes of this phenomenon Urban heat island. Reduced vegetation cover in urban areas due to urban surface development for the needs of human activities such as settlements, offices, industry, and other functions is an environmental consequence that often occurs in cities.

Urban heat island (UHI) is a phenomenon that has occurred in all areas of big or small cities in Indonesia. All cities regardless of size develop a distinct climate that is distinct from the regional macroclimate in which they are located, although the characteristics of the urban microclimate depend on the larger climate. (Paska Ariandy Iswanto, 2008). Phenomenon urban heat island (UHI) generally occurs in urban areas as centers of community economic activity. UHI is a residential area that has a higher temperature than the surrounding area (Sukojo & Hauzan, 2023). This is due to the sun's heat being trapped in urban areas due to green open land that has changed into built-up land, even though the density of vegetation has a very important role in lowering surface temperatures.

The UHI phenomenon is a form of environmental damage in the form of decreased air quality, this affects human health, energy use, and climate change (Kershaw et al., 2010; Lai & Cheng, 2009; Ng & Ren, 2018; Skelhorn et al., 2018; Stone et al., 2010; Tan et al., 2010) in (Fawzi, 2017). This of course will affect the quality of the environment. UHI has a negative impact in the form of a decrease in health and environmental quality, energy resources, and climate dynamics which will affect the activities of urban areas, so it needs to be addressed (Hu & Jia, 2010; Jin et al., 2005; Tayanc & Toros, 1997; Tran et al., 2006). (Shishegar, 2014) explained that one of the effective and efficient efforts to reduce UHI as well as to improve the quality of life and health of urban communities is to add green open spaces.

Phenomenon-related research on urban heat islands (UHI) has been carried out by various researchers around the world, especially using remote sensing imagery. Remote sensing technology is one of the technologies that can be used to analyze the UHI phenomenon. (Du et al., 2019) conducted research in the Yangtze River Delta by linking a combination of surface effect surban heat island, landscape composition, and configuration. Subsequent research conducted by (Aslan & Koc-San, 2016) in Antalya City, Turkey used Landsat 7 ETM+ and Landsat 8 OLI/TIRS imagery to detect potential UHI and relate it to land cover/use with an increase in UHI intensity of 1.2°C from 2001 to 2014. However, research related to this phenomenon in urban heat islands using remote sensing techniques is still relatively rare, especially in Indonesia, so the advantages and disadvantages are not widely known. From the explanation above, it is necessary to have a special study of the phenomenon of urban heat islands using new technologies in remote sensing techniques that are based on the cloud.

The development of remote sensing technology is characterized by image-based processing cloud where is the storage form hard disk and memory makes it inflexible and very limited in processing. based processing cloud currently popular is using the Google Earth Engine (GEE). (Gorelick et al., 2017) stated that GEE is a platform that offers cloud-based environmental data analysis for free (open source). This platform has the advantage of providing Application Programming Interfaces (APIs) that use JavaScript and Python and can be hosted on GitHub. The existence of satellite imagery and image processing algorithms based on the cloud makes it possible to make observations on the city of Cimahi with a different temporal.

With the development of sophisticated cloud-based remote sensing technology, one of its implementations can be used to calculate changes in vegetation area and distribution of city surface temperatures. The purpose of this research is to map multitemporal spatial changes in the vegetation index (MSAVI) and soil surface temperature (LST) in Cimahi City in 2015, 2019, and 2023 and to analyze their relation to the phenomenon and the wide distribution Urban heat island using Landsat 8 imagery by integrating techniques cloud computing Google Earth Engine. The choice of the Landsat 8 image type is because it can provide information about the surface temperature that is quite valid and easy to access.

Based on this thought, it is necessary to study the characteristics of spatial changes in the phenomenal urban heat island multi-temporally in Cimahi City as one of the core cities of the city system in the Bandung Basin Region and has an important function in supporting the lives and livelihoods of residents in urban areas and the surrounding area.

2. DATA DAN METHODS

Analysis of phenomenal urban *heat island* using remote sensing methods. The data used in analyzing the phenomenon of urban *heat islands* in Cimahi City using field survey data and Landsat 8 imagery as primary data. Landsat Imagery data is the result of the earth resources program developed by NASA (National Aeronautics and Space Agency) United States in the early 1970s (Sukristiyanti & Marganingrum, 2009).

The stages in research are divided into five stages, namely:

1. **Preparation** is in the form of careful preparation so that when implementing constraints or obstacles can be minimized. The preparation includes the data and materials needed during the research. Researchers prepared primary data including Landsat-8 OLI/TIRS imagery as primary data.
2. **Data collection** in the form of a literature study on Landsat-8 OLI/TIRS imagery data in the study area.
3. **Processing** phenomenon analysis data on urban *heat islands* was carried out by extracting data on land surface temperature (LST) and vegetation density index (MSAVI) in the Google Earth Engine.
4. **Data analysis** was carried out by observing changes in vegetation density in Cimahi City using the MSAVI algorithm to obtain the value of vegetation density and surface emissivity *(land surface emissivity)*.

MSAVI processing requires red and near-infrared bands using the equation (Wen et al., 2020)

$$\text{MSAVI} = \frac{2\rho_{NIR}+1-\sqrt{(2\rho_{NIR}+1)^2-8\,(\rho_{NIR}+(\rho_{red})}}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(1)}$$

Surface temperature processing refers to research (Fawzi, 2017) with the equation:

$$TS = \frac{T}{(1+\frac{\lambda T}{\partial}\,\text{In}\,\varepsilon)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

Information:

TS = Surface temperature

T = Brightness temperature

λ = Mid wavelength of Landsat 8 thermal band

∂ = Resolution 1.438 x 10-2mK

€ = Emission Value

After calculating MSAVI and LST, identification of phenomena is carried out urban heat island with a remote sensing method based on the threshold of surface temperature processing (LST) in 2023. From the surface temperature data, the UHI phenomenon was identified by reducing it with the UHI threshold value according to (Fawzi, 2017; Ma et al., 2010)

$$\text{UHI} = T_{Mean} - (\mu + \frac{\alpha}{2}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(3)}$$

Information:

T_{Mean} = Average value*(mean)* from LSTs

α = Standard deviation value of LST

5. **Field surveyor ground** *checking* as an effort to test its accuracy after being given a sample point.
6. **Conclusion** in the form of analysis results obtained.

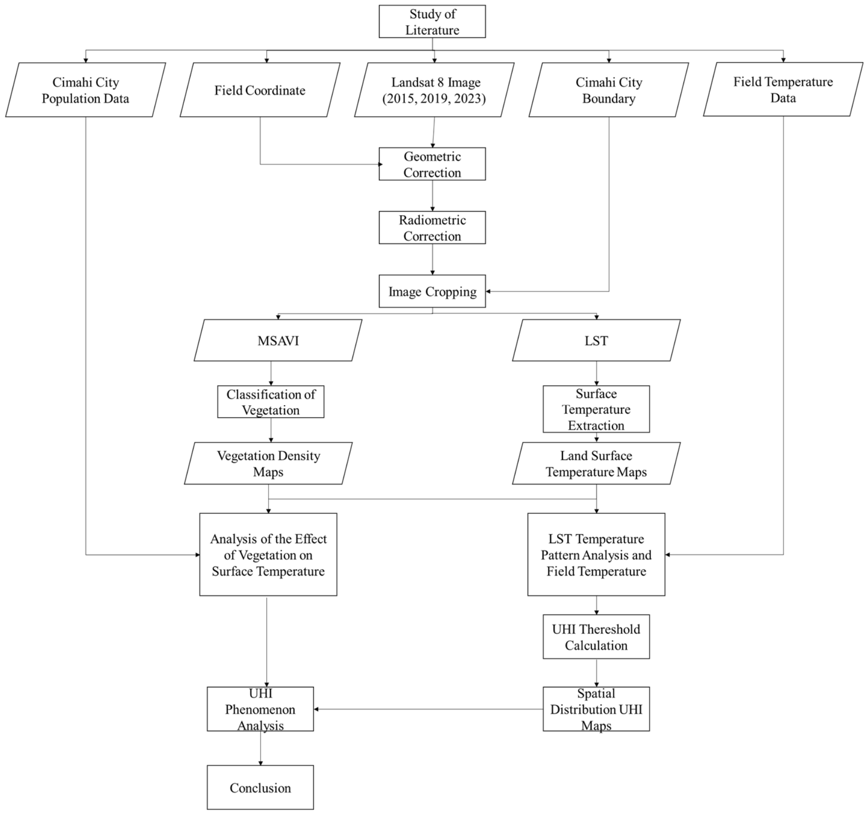

Figure 1. *Research Flowchart*
Source: 2023 Analysis Results

3. RESULTS AND DISCUSSION

A. Vegetation Change Analysis *(Modified Soil Adjusted Vegetation Index)*

The results of the classification of changes in vegetation density using Modified Soil Adjusted Vegetation Index shown in Figure 2. The non-vegetation density class dominates the southern and central areas of Cimahi City as the center of regional activity. The low and moderate vegetation density class is spread over the Cimahi City area, while the dense and very dense density class dominates the northern area and a small part of the western outskirts of Cimahi City. Vegetation density in Cimahi City as a result of the MSAVI visualization can be seen in Figure 2.

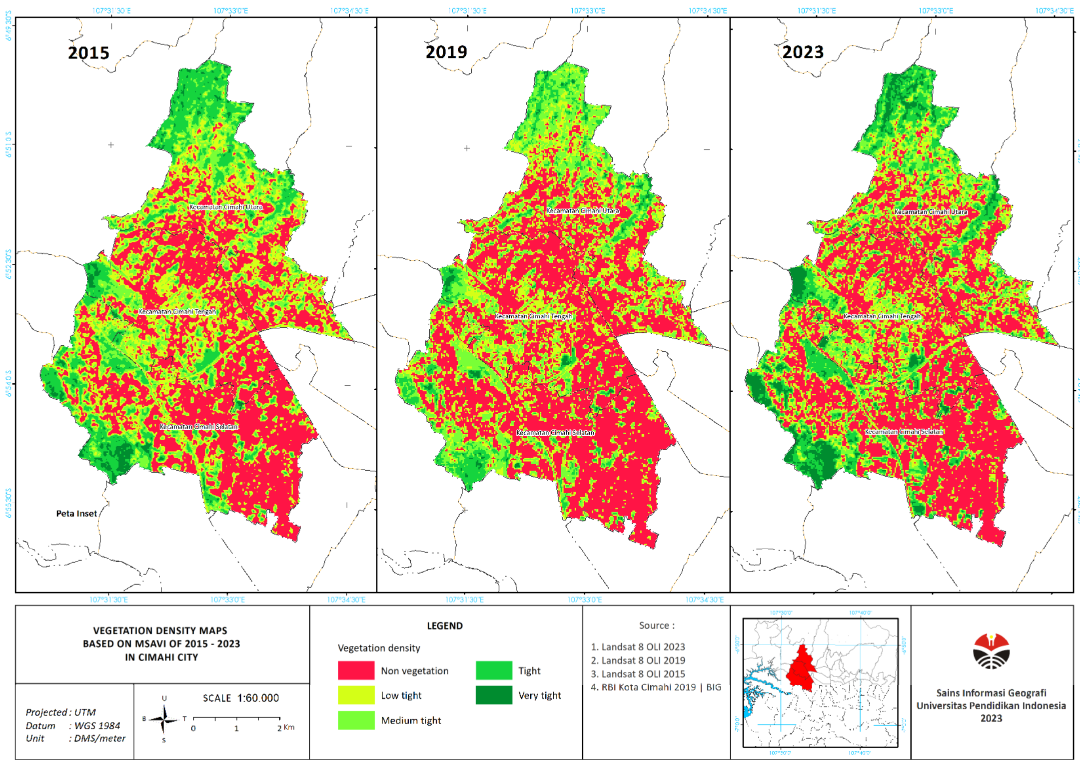

Figure 2. Vegetation Change Map (MSAVI) for 2015-2023 in Cimahi City

Source: 2023 Analysis Results

From Figure 2 the change in the density of vegetation in Cimahi City is very significant in built-up land and vegetation. In 2015 the very dense vegetation density class had an area of 94.05 Ha, and the non-vegetation density class had an area of 1736.82 Ha. In 2019 the very dense vegetation density class decreased with a total area of 36.18 Ha and the non-vegetation density class increased to 2080.89 Ha. However, in 2023 the very dense vegetation density class will increase by 224.91 Ha and the non-vegetation density class will decrease with a total area of 1480.23 Ha. This shows that there is development activity with the conversion of vegetation land to built-up land from 2015 to 2023. Following are the results of the area of vegetation density class for 2015 – 2023 Cimahi City in Table 1.

Table 1. *Area of Cimahi City Vegetation Density Class*

Year	Cimahi City Vegetation Density Class Area (Ha)				
	non vegetation	low	currently	tight	very tight
2015	1736.82	972.09	696.87	620.01	94.05
2019	2080.89	932.31	793.71	276.75	36.18
2023	1840.23	882.27	626.4	546.03	224.91

Source: 2023 Analysis Results

B. Temperature Change Analysis (Land Surface Temperature)

Surface temperature data processing (land surface temperature) in Cimahi City gives the results in Figure 3 and Figure 4.

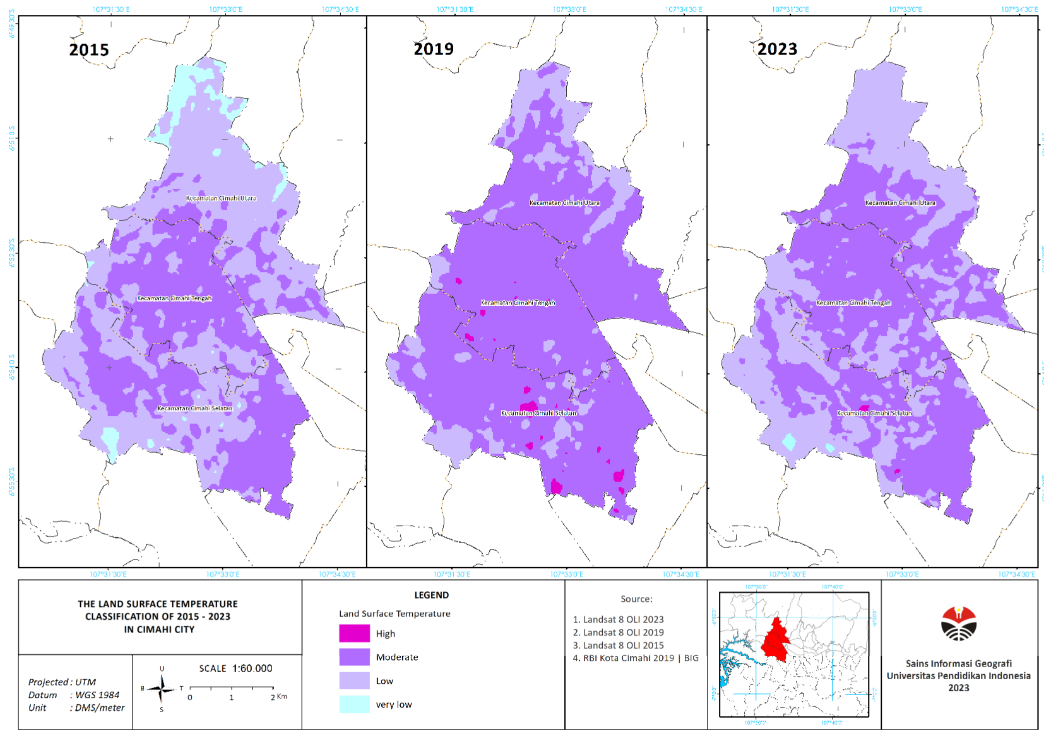

Figure 3. Map of Changes in Surface Temperature (LST) for 2015-2023 in Cimahi City
Source: 2023 Analysis Results

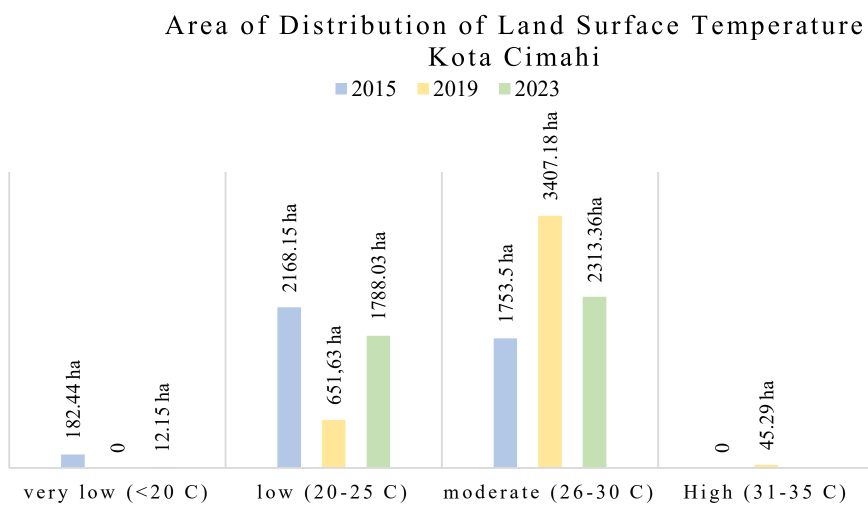

Figure 4. Area of Distribution of Surface Temperature (LST) in 2015-2023 in Cimahi City
Source: 2023 Analysis Results

Based on the analysis results from Figure 3 and Figure 4 it can be seen the surface temperature land surface temperature (LST) in Cimahi City has fluctuated from 2015 to 2023. The 2019 LST was higher than the temperatures in 2015 and 2023. This is very visible in the classification of temperature ranges moderate and high that the temperature area in 2019 was higher than in 2015 and 2023. The decrease in the lower surface temperature range in 2023 compared to 2019 was caused by natural factors. This decrease in temperature is caused by atmospheric dynamics on a regional to local scale which presents opportunities for rain in several regions of Indonesia, especially on the island of Java. This atmospheric dynamic plays a significant role in triggering an increase in cloud growth thereby causing the potential and intensity of rain.

Surface temperature with classification range very low (<20 °C) only found in processing surface temperatures in 2015 and 2023. Results of classification of temperature ranges low (20 –25 °C) dominated by surface temperature processing in 2015. Temperature range moderate (26 – 30 °C) in 2019 is more dominant in Cimahi City. temperature range high (31–35 °C) is only available in the processing of 2019.

C. Correlation Analysis of Surface Temperature with Vegetation Index

This research was validated by examining processing temperature data with vegetation to determine the relationship between the two. The correlation of the processed LST data in the image and the vegetation data in the image can be seen by performing a simple linear regression analysis. The results of the linear regression analysis obtained an equation that shows how big the relationship is with the two variables. In Figure 5 it can be seen the results of the linear regression of the two variables.

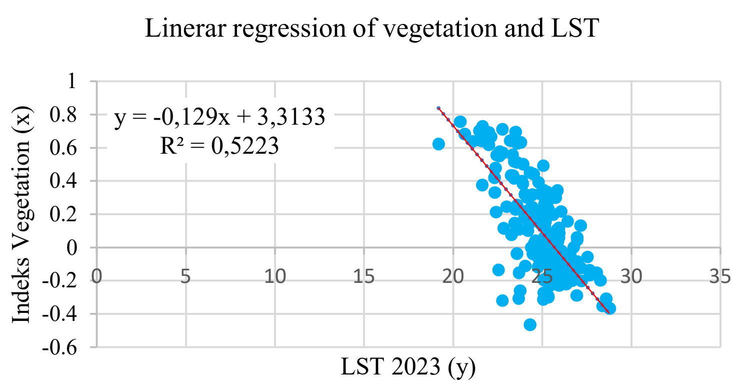

Figure 5. Linear Regression Results for Change in Vegetation Area to Surface Temperature
Source: 2023 Analysis Results

The results of the linear regression analysis obtained the equation $y = -0.129x + 3.3133$. The equation obtained shows a positive/directly proportional relationship between the LST processed temperature and the MSAVI vegetation index. A positive relationship is indicated by a positive symbol (+) which is before the regression coefficient. From this equation, we also get a coefficient of determination of 0.5223 which indicates that there is an influence so that if the field surface temperature increases, the vegetation index from the image decreases or vice versa if the field surface temperature decreases, the vegetation index from the image increases.

In addition to looking for the correlation value between the field temperature variable and the vegetation index from Landsat-8 imagery, a pattern description between image temperature data and field temperature data is also sought. From the results of plotting the data it can be seen that the entire sample has almost the same pattern of increase and decrease.

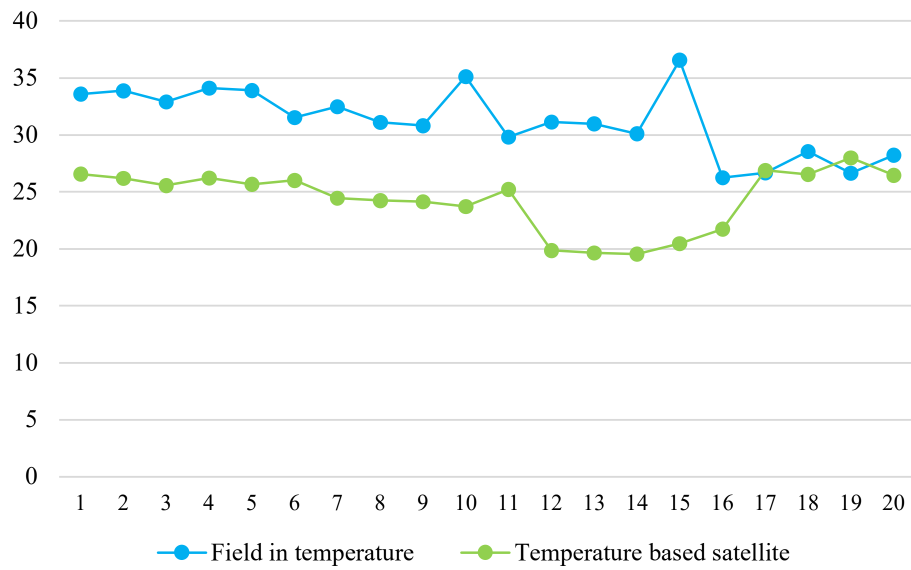

Figure 6. Field Data Patterns and Processing Results
Source: 2023 Analysis Results

D. Analysis Phenomena *Urban Heat Island*

The distribution of the UHI phenomenon in Cimahi City is obtained based on the threshold value of processing land surface temperature every year. The threshold value is obtained from the calculation of the average temperature in the area sub-urban then set the minimum value of the temperature. The threshold value for temperature processing each year can be seen in table 2.

Table 2. *UHI Threshold Values*

Year	Threshold (C)
2015	25,28 C
2019	27,79 C
2023	26,71 C

Source: 2023 Analysis Results

The threshold value in Table 2 is then classified. Surface temperatures that have values lower than the UHI threshold are called non-UHI. The temperature that is higher than the UHI threshold is called the area where the UHI phenomenon occurs. The results of the distribution of the UHI phenomenon are seen in Figure 6 and Table 3.

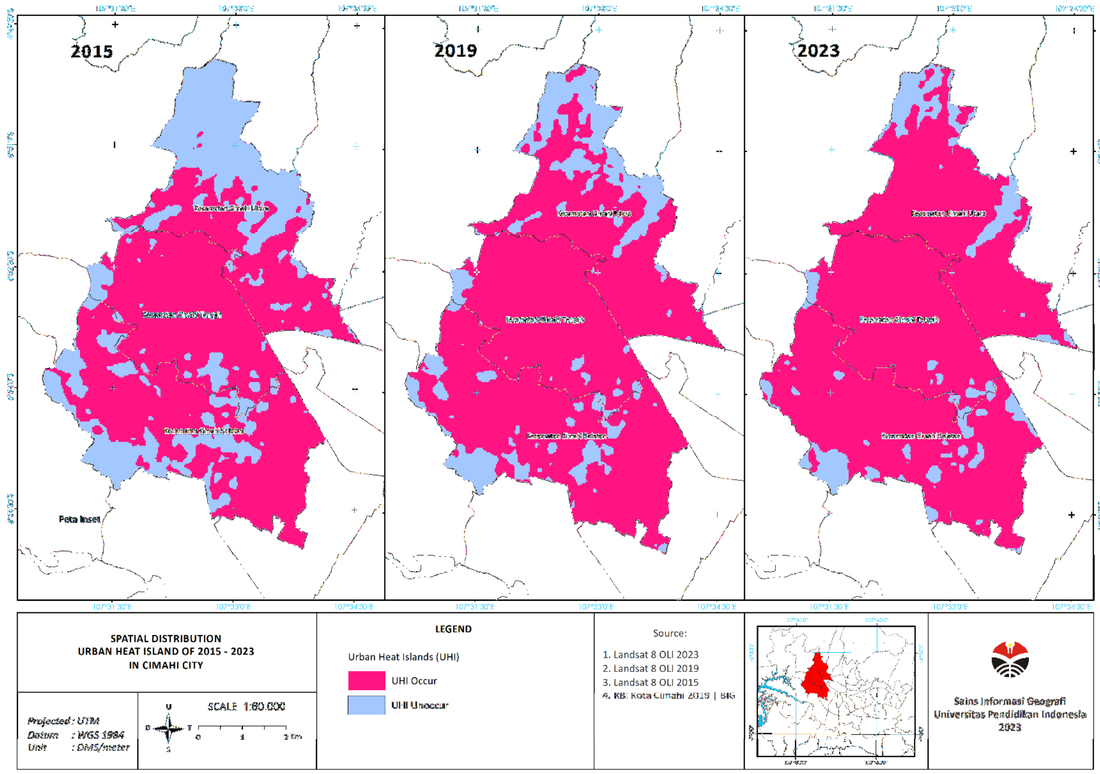

Figure 7. UHI Phenomenon Map for 2015-2023 in Cimahi City
Source: 2023 Analysis Results

Table 3. Broad phenomena Urban heat islands

Year	UHI phenomena area (ha)	
	UHI Occur	UHI Un occur
2015	1319.94	2799.9
2019	3389.04	730.8
2023	3634.06	470
Change	(-) 2314.12	(+) 2,330

Source: 2023 Analysis Results

The widespread distribution of the UHI phenomenon in Cimahi City has increased every year. In 2015 the area affected by the UHI phenomenon was 1319.94 hectares or 32.9 percent of the area of Cimahi City. In 2019 the area affected by the UHI phenomenon in Cimahi City increased significantly with an area of 3389.04 Ha or 84.72 percent of the total area of Cimahi City. Meanwhile, in 2023 the area affected by the UHI phenomenon will be 3,634.04 hectares or 90.85 percent of the area of Cimahi City. This shows an increase in temperature from the threshold value and a change in land function into built-up land in the range of 2015 to 2023 in Cimahi City. The distribution of the UHI phenomenon in each sub-district in Cimahi City can be seen in Table 4. It can be seen from Table 4 that the area that dominates the impact of the UHI phenomenon, namely South Cimahi District with a total affected area of 1440.43 Ha.

Table 4. *Area of Cimahi City Vegetation Density Class*

Sub district	UHI Phenomena	Year		
		2015	2019	2023
		Area (ha)	Area (ha)	Area (ha)
North Cimahi	UHI Un occur	725.73	407.08	221.71
	UHI Occur	660.69	979.34	1164.71
Central Cimahi	UHI Un occur	123.68	59.93	50.68
	UHI Occur	955.92	1019.67	1028.92
South Cimahi	UHI Un occur	461.19	257.61	197,662
	UHI Occur	1176.9	1380.48	1440.43

Source: 2023 Analysis Results

E. Urban Heat Island Impacts and Mitigation

Increased temperatures from the urban heat island phenomenon, especially during summer, can affect the environment and people's quality of life. Although some impacts may be beneficial, such as extending the growing season of crops, most of the impacts are negative. The conversion of land into built-up areas in Cimahi City has reduced the amount of green open space that should be owned to achieve ecological balance. This condition makes the city accumulate heat energy by storing or releasing it during the day. This makes the city hotter than the periphery, decreasing the comfort level of the city community and causing a lot of pollution, poor air circulation, and low humidity levels (Khambali & ST, 2017).

In addition, there is an increase in air pollutant emissions due to the urban heat island phenomenon in Cimahi City. Data from previous research on Particulate Matter 2.5 (PM2.5) exposure in 2021 shows that all location points spread across five PM2.5 measurement points in Cimahi City are still below environmental quality standards. PP No. 41 of 1999 concerning Environmental Pollution Control for National Ambient Air Quality Standards. (Saputra & Akmal, 2021). The increase in air pollutant emissions is caused by several factors including human activities such as vehicle exhaust gases, factory pipe exhaust fumes, and the transportation sector which is the trigger for the urban heat island phenomenon.

There are many ways to reduce the negative effects of urban heat islands due to uncontrolled urban growth with proper mitigation. Mitigation of urban heat island needs to be designed to minimize the adverse impacts that can occur. Mitigation can be done by analyzing the factors that trigger the occurrence of UHI, for example by setting development directions, the use of environmentally friendly house or building models, and directions to reduce carbon production. According to Voogt and Oke (Voogt & Oke, 2003) in (Darlina et al., 2018) mitigation measurement efforts can be known from the shape of the city (material, geometry or geometry, green open space), and city functions (energy use, water use, and pollution). However, the addition of vegetation is considered the best thing to reduce the temperature, the presence of vegetation can reduce the average air temperature by 2°C (Susca et al., 2011) to 4°C (Wang & Akbari, 2016)in (Fawzi, 2017).

In addition, the use of green roofs on building roofs is one of the alternative solutions to overcoming the warming effect that occurs in Cimahi City. Green Roof is a term that refers to the roof of a building where part or all of the roof surface is covered with vegetation or plant media and coated by a waterproofing membrane. This helps to balance air humidity and increase the area of green open space in Cimahi City.

4. CONCLUSIONS

Changes in vegetation density based on MSAVI processing showed that there was a decrease in the area of very dense and dense vegetation, but there was an increase in the area of non-vegetation density in the range of 2015 and 2019, then decreased in 2023 but not significantly.

Changes in temperature based on LST processing show that the average temperature in 2015 was 24.23 C then increased to 26.88 in 2019 and decreased to 25.89 in 2023. The effect of vegetation density on surface temperature (LST) has a correlation value of 0.5223 which shows the level of strong relationship, or it can be said that the density of vegetation affects the LST surface temperature value which is one of the variables urban heat island in Cimahi City.

The results of the analysis of the distribution phenomena urban heat island in Cimahi City shows that, in the span of 2015, 2019, and 2023 there has been an increase in the phenomenon urban heat island. The area covered by the phenomenon urban heat island in Cimahi City it reached 1319.94 Ha or as large as the area of Cimahi City in 2015, then increased to an area of 3389.04 Ha or as much as a percent of the area of Cimahi City in 2019 and increased again in 2023 to an area of 3634.04 Ha or equal to percent of the area of Cimahi

City. The predominant area is affected urban heat island occurred in South Cimahi District with an area affected of 1440.43 Ha, so efforts need to be made to minimize the occurrence urban heat island which will impact the environment.

In addition, further research is needed in the long term to find out trend occurrence of the UHI phenomenon, including intensity, location distribution, and its relation to climatological factors to mitigate the impact of the UHI phenomenon.

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