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SPATIAL TEMPORAL VARIATION OF LAND SURFACE TEMPERATURE IN AMBON CITY CENTER AREA

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Abstrak

Perubahan penggunaan lahan dari vegetasi menjadi lahan terbangun di Kawasan Pusat Kota Ambon mempengaruhi peningkatan suhu permukaan daratan dan menciptakan fenomena urban heat island, yang berpotensi memengaruhi iklim lokal dan global. Metode yang digunakan dalam penelitian ini adalah analisis citra satelit Landsat 8 melalui Google Earth Engine (GEE), yang memungkinkan pemrosesan data secara efisien dan akurat. Hasil analisis menunjukkan bahwa suhu permukaan tertinggi di kawasan tersebut meningkat dari 27,35°C pada tahun 2015 menjadi 29,30°C pada tahun 2025, sementara suhu terendah juga mengalami kenaikan. Temuan ini menegaskan perlunya perhatian terhadap strategi pengelolaan tata ruang yang berkelanjutan untuk mengurangi dampak negatif dari urbanisasi, menjaga kualitas lingkungan, serta meningkatkan kualitas hidup masyarakat di Kota Ambon.

Kata Kunci: Ambon; GEE; Landsat 8; Suhu permukaan daratan

Abstract

Land use change from vegetation to built-up land in Ambon City Center affects the increase of land surface temperature and creates the urban heat island phenomenon, which has the potential to affect local and global climate. The method used in this research is the analysis of Landsat 8 satellite images through Google Earth Engine (GEE), which enables efficient and accurate data processing. The analysis shows that the highest surface temperature in the region increases from 27.35°C in 2015 to 29.30°C in 2025, while the lowest temperature also increases. These findings confirm the need for attention to sustainable spatial management strategies to reduce the negative impacts of urbanization, maintain environmental quality, and improve the quality of life of people in Ambon City

Keywords: Ambon; GEE; Landsat 8; Land Surface Temperature

1. Introduction

The growth of urban areas cannot be separated from urbanization (Hegazy & Kaloop, 2015). Urbanization is defined as a process of development and expansion of a city, which can also be seen from the growth and development of the population concentration in that city, because the growth and development of the city's population concentration are also related to the process of increasing urban activities in urban areas (Maarseveen et al., 2018). The development of an area is certainly accompanied by an increase in the population (Han & Sun, 2019). The increase in the population in a region is related to land use, especially land for housing and its supporting facilities, because along with population growth, the demand for land for housing also increases (Latue et al., 2023). This has an impact on land use changes due to the demand for land to meet the needs of the urban population, which then spreads to the outskirts of the city that were originally villages and have become an important part of the city (Hegazy & Kaloop, 2015; Salakory, & Rakuasa, 2022). Physically, the development of a city can be seen from the increasing population, the closer proximity of buildings, and the expanding settlements, as well as the more complete urban facilities that support the city's social and economic activities (Maarseveen et al., 2018: Rakuasa & Budnikov, 2024). The demand for land allows for changes in land use, from previously undeveloped land to developed land (Araújo de Oliveira, 2022).

Changes in land use in urban areas will later cause the land surface temperature in urban areas to be higher compared to the surrounding areas (Maulana & Bioresita, 2023; Rakuasa et al., 2024). This phenomenon is called the urban heat island, characterized by significantly higher land surface temperatures in densely built environments compared to rural air temperatures (Mughal et al., 2020). Heat islands are formed when some of the vegetation cover is replaced by asphalt, concrete, and bricks, which later contribute to increased heat by storing and releasing solar energy, causing urban heat islands in the city to rise (Li et al., 2020). The increase in surface temperature is also one of the factors contributing to global climate change because, according to the IPCC report (2013), development can impact various climate change phenomena such as polar ice melting, rising sea levels, and, as previously discussed, the increase in air temperature (Rakuasa et al., 2024).

In the past, research on land surface temperature used direct measurement methods in the area designated as the research location. However, with the advancement of technology, climate studies on land surface temperature using satellites have begun to develop over the past three decades, making it easier to conduct research on land surface temperature occurring in a specific area (Moazzam et al., 2022). This research uses satellite imagery to observe land surface temperatures and the urban heat island phenomenon occurring in the research location, which is the central area of Ambon City.

Ambon City as the capital of Maluku Province continues to experience increasing population growth and rapid urban development (Rakuasa & Latue, 2023), this is because Ambon City is not only the provincial capital, but also the center of various sectors including the socio-economic, education, industrial, government and tourism sectors (BPS, 2024). Previous research conducted by Rakuasa et al., (2023), showed that residential land in the central area of Ambon City from 2001 was 1,221.71 Ha, in 2012 it was 1,283.16 Ha, and in 2021 it was 1,372.28 Ha which continued to increase in area and of course had an impact on the increase in land surface temperature.

The development of advanced technology has helped in dealing with problems, one of which is the problem of increasing land surface temperature in urban areas. Research on the increase in land surface temperature due to land use change is also increasing with remote sensing technology (Tahooni et al., 2023). According to Mansourmoghaddam et al. (2023), surface temperature analysis can be done using GIS & remote sensing technology. The development of science and information technology in the geographical field which is increasingly sophisticated can be seen from the processing and analysis of geographic (spatial) data that is already based on cloud computing which has made it easier for users to carry out spatial temporal analysis of surface temperature (Kafy et al., 2020). The conventional method used in analyzing land surface temperature takes a long time because it must be done by downloading satellite image data and continuing with data processing using satellite image processing software, besides that it requires a computer that has high performance so that the image processing process can run smoothly (Rakuasa, 2022). This is costly and time-consuming, especially when the analysis is conducted on a time series basis over a large research area.

In 2010 Google launched a technology called Google Earth Engine (GEE) (Mutanga & Kumar, 2019). This geospatial analysis platform provides satellite imagery data that can be accessed online for free, so that users can perform various kinds of analysis on the earth's surface in real time (Mutanga & Kumar, 2019). GEE allows users to process georeferenced satellite images stored in the GEE archive (cloud) by building an algorithm to run it (Ermida et al., 2020).

Surface temperature analysis in the Ambon City Center area can be done based on cloud computing using the Google Earth Engine Platform. Google Earth Engine (GEE) is an excellent geospatial analysis platform for cloud processing of satellite images and other geospatial data based on the cloud with free / open source (Muntaga, 2019). This platform has the advantage of providing Application Programming Inerface (APIs) that use JavaScript and Python and can be hosted on Github (Onisimo Muntaga, 2019). Google Earth Engine (GEE) provides convenience in analyzing spatial data, including in processing spatial data users do not need to require a computer with high specifications with a stable internet connection, data can be processed quickly, historical satellite image data available in GEE for more than 40 years and spatial data sets that are updated and expanded daily and have more than seventy petabytes of public geospatial datasets, including Landsat, Sentinel, and MODIS satellite image data (Diksha et al., 2023). Based on this background, this study aims to determine the spatial variation of land surface temperature in Ambon City in 2015 and 2025 using Google Earth Engine.

2. Methods

This research was conducted in the central area of Ambon City, Ambon Island, Maluku Province, Indonesia (Figure 1). The data used in this study are shp data of Ambon City Center Detailed Spatial Plan obtained from the Geospatial Information Agency and PlanetScope image data obtained from the United States company Planet. The satellite image data used is Landsat 8 Collection 1 Tier 2 TOA Reflectance which is accessed and analyzed on Google Earth Engine (https://earthengine.google.com/). Landsat 8 Collection 1 Tier 2 TOA Reflectance satellite imagery is a product of atmospheric correction. Spatial and temporal variations of land surface temperature in the central area of Ambon City were analyzed in 2015 and 2025.

To analyze the land surface temperature (LST) in Landsat 8 images using Google Earth Engine (GEE) based on cloud computing by using the Split-Window Algorithm formula. Data processing and analysis were conducted entirely in the GEE platform. Data analysis in the GEE platform begins with selecting the satellite image data used, namely (Landsat 8 Collection 1 Tier 2 TOA Reflectance), by entering the script code:

```
var image = ee.Image('LANDSAT/LC08/C01/T1_TOA/LC08_1234567890123456789');
```

After selecting the satellite image used, then determine the time range of analysis, namely the 2015 and 2025 periods by entering the script code:

```
filterDate ('2015-01-01^',(_^')2015-03-01^' ),('2025-01-01^',(_^')2025-03-01^' ).
```

The next step is to convert the radiance temperature into surface temperature (LST) by using the unit °C, by entering the script code:

```
var LST = image.expression(
'(Tb/(1 + (0.00115 * (Tb / 1.4388) / 1.2) * log(Ep)))', {
'Tb': image.select('B10'), // Brightness temperature in band 10 'Ep': image.expression(
'(((10.8 * (Tb - 273.15)) / ((exp((10.8 * (Tb - 273.15)) / 14387.69) - 1))) + 1)', {
'Tb': image.select('B10') // Brightness temperature in band 10
}).rename('Ep')
}).rename('LST');
```

After the process of converting the radiance temperature into surface temperature, the LST data was then cut using the Ambon City center area boundary command: clip (Ambon City Center

Area);. The results of the land surface temperature analysis obtained are then exported to Google Drive for further analysis in Arc Map 10.8 software using the command:

```
Export.image.toDrive({ image: LST,
description: 'LST_Image' scale: 30,
region: Kawasan Pusat Kota Ambon //
});
```

The LST data was then downloaded and further analyzed in Arc Map 10.8 software by classifying it into 5 classes, namely temperature <21℃: very low, 21-22℃: low, 22-23℃: medium, 23-24℃: high, >24℃ is defined as very high temperature (Latue, 2023).

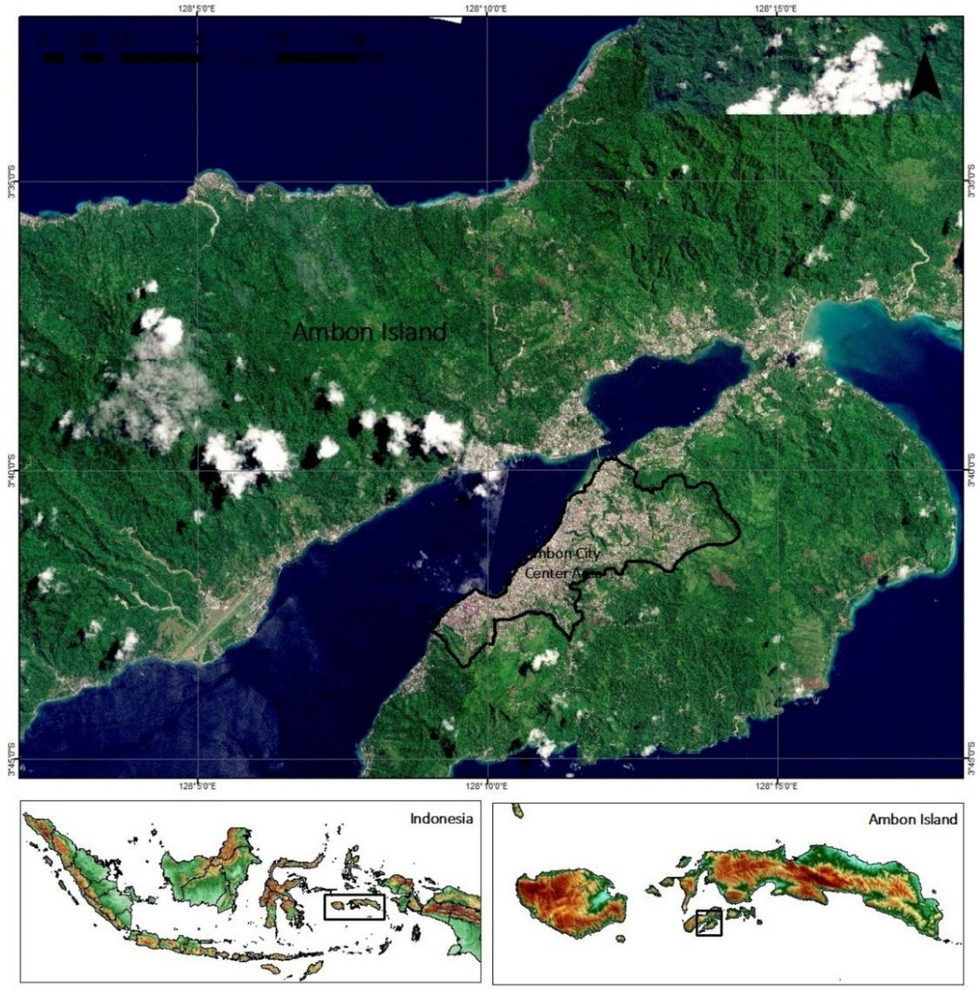

Figure 1. Research Location

3. Results and Discussion

The land surface temperature in the central area of Ambon City is obtained through the processing of Landsat 8 image data in 2015 and 2025 which is divided into five classes. In 2015, the lowest temperature in the research location is 18.61℃ and the highest is 27.35℃ while in 2025 the lowest temperature is 18.80℃ and the highest temperature is 29.30℃. In 2015, the LST value with the largest area presentation is the LST value of 21-22℃ at 23.51%, the LST value of 23-24℃, at 23.40%, the LST value of 22-23℃ at 20.17%, and the LST value < 24℃ at 10.49%.

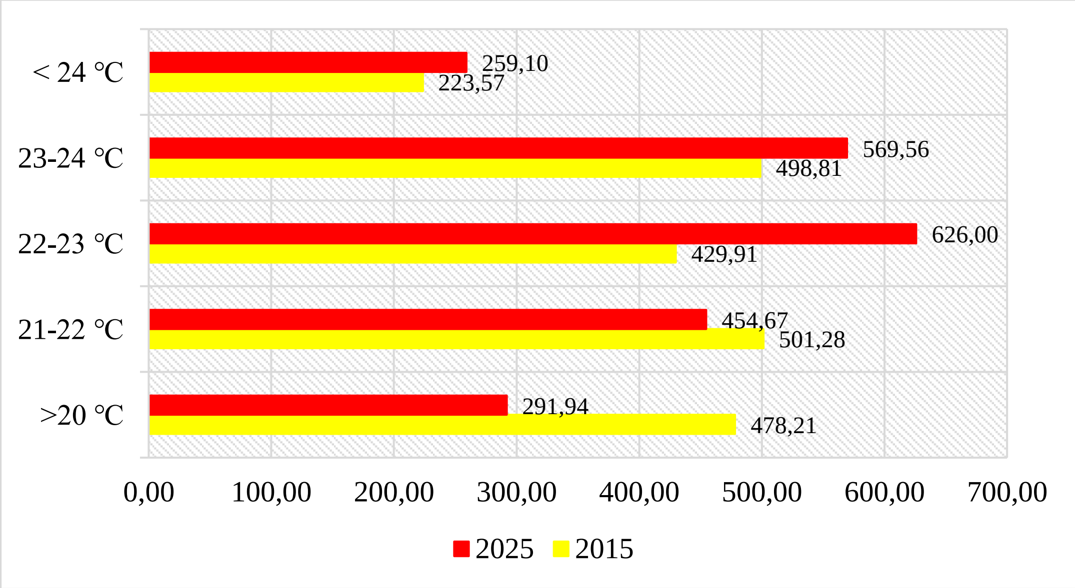

Figure 2. Area (Ha) of LST (°C) in the period 2015 and 2025

In 2025, the LST value with the largest area presentation is the LST value of 22-23°C, amounting to 28.44%, followed by the LST value of 23-24°C at 25.87%, the LST value of 21-22°C at 20.65, the LST value >20°C at 13.26%, and the LST value <24°C at 11.77%. Based on Figure 2, the very high land surface temperature (<24°C) continues to increase in area from 223.57 hectares (2015) to 259.10 hectares in 2025 while the very low LST value (>20°C) continues to decrease in area from 478.21 hectares in 2015 to 291.94 hectares in 2025. Spatial variations of land surface temperature changes in 2015 and 2025 can be seen in Figures 3 and 4.

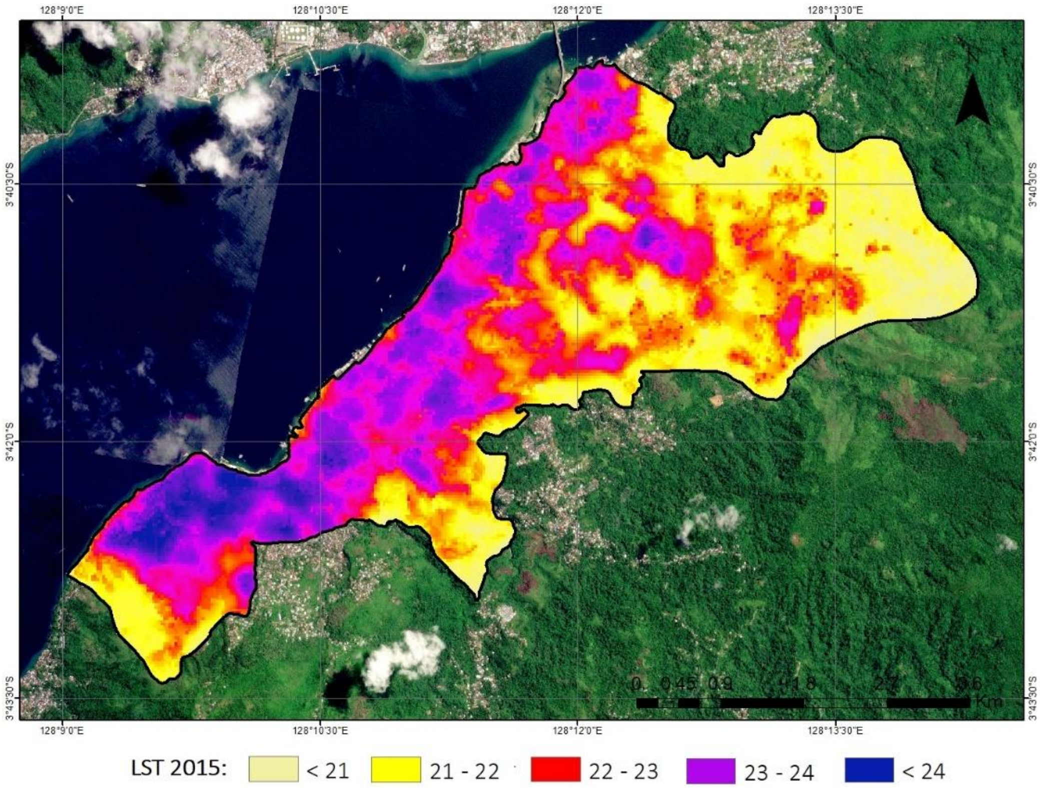

Figure 3. Land Surface Temperature (°C) in 2015

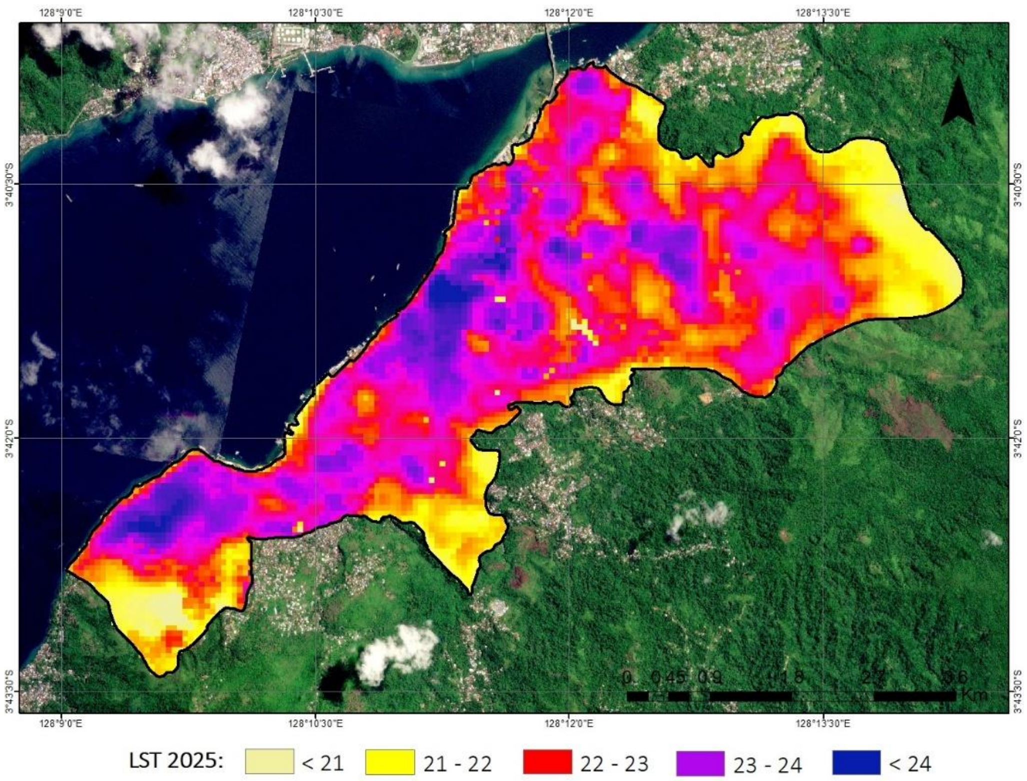

Figure 4. Land Surface Temperature (°C) in 2025

One of the main factors contributing to the increase in temperature in Ambon City center is the urban heat island (UHI) phenomenon. The rapid urbanization process causes agricultural land and vegetation to be replaced by buildings and infrastructure, thus reducing the vegetation cover that functions to absorb heat (Hu et al., 2023). According to previous research, residential land in Ambon City Center continues to grow, from 1,221.71 ha in 2001 to 1,372.28 ha in 2021 (Rakuasa et al., 2023). This shows that more built-up areas can increase surface temperature because building materials such as asphalt and concrete have a higher ability to store and release heat compared to vegetation. The spatial relationship between residential development and LST can be seen in Figure 5.

The analysis method used in this study has proven effective in monitoring surface temperature variations by utilizing remote sensing technology. By using the Google Earth Engine (GEE) platform, the processing of satellite images can be done more quickly and efficiently (Gorelick et al., 2017). This method allows researchers to obtain accurate data on surface temperature on a large scale and in a shorter period of time, compared to conventional methods that take longer and cost more (Arévalo et al., 2020).

The analysis also shows that there is a significant variation in surface temperature based on the classification. The temperature classification is divided into five categories: very low, low, medium, high and very high. In 2015, the temperature with the largest area presentation was located in the 21-22°C category at 23.51%, while in 2025 a significant change was observed, where there was an increase in the number of areas classified as high (>24°C). This indicates that the impact of urbanization is becoming more pronounced, with environmental consequences to watch out for.

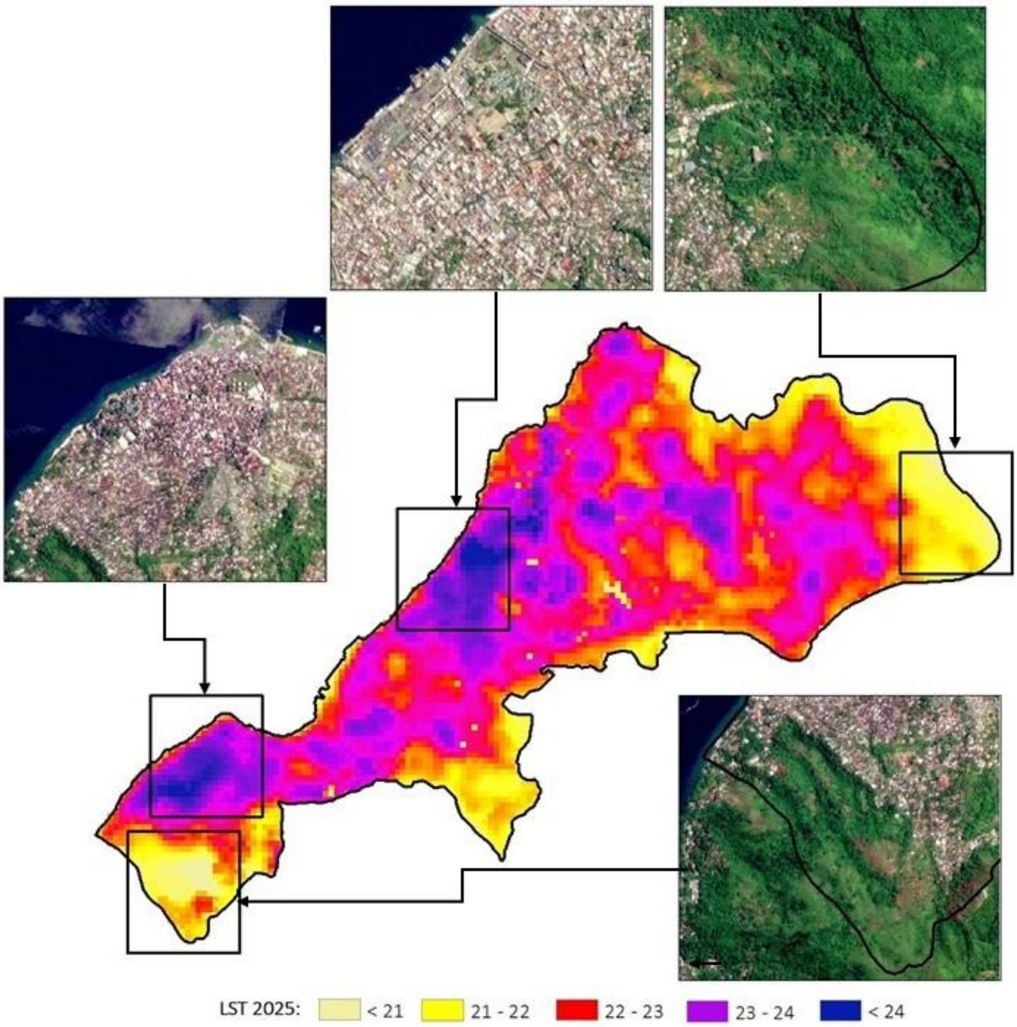

Figure 5. Spatial view of LST with PlanetScope natural color image visualization.

Rising land surface temperatures not only impact local climate, but also have broader implications for global climate change (Namkhan et al., 2022). According to a report from the IPCC (2013), unplanned infrastructure development can add to the burden of climate change problems, such as rising air temperatures and other phenomena. As temperatures continue to rise, risks such as melting polar ice caps and rising sea levels will become more apparent, potentially threatening ecosystems and human life in coastal areas (Sianturi et al., 2024). In order to meet these challenges, it is essential to implement sustainable urban management strategies. This includes spatial planning that takes into account the sustainability of the environment, by increasing green areas that can serve as a cooler in the midst of urban density. In addition, more attention needs to be paid to the integration of technology in managing surface temperature monitoring and land use change. Through continuous research, it is hoped that stakeholders can formulate appropriate policies to address the negative impacts of urbanization and maintain the quality of life of the community.

4. Conclusions

The results showed that the increase in land surface temperature in the central area of Ambon City between 2015 and 2025 was strongly influenced by the phenomenon of urbanization and land use change. The data shows a significant upward trend in temperature due to land conversion from vegetation to urban infrastructure, resulting in the urban heat island phenomenon. The use of remote sensing technology through Google Earth Engine enables more efficient and accurate temperature monitoring, which is important in formulating sustainable urban management strategies. Therefore, serious attention to spatial planning and environmental policies is needed to reduce the negative impacts that can exacerbate climate change and the quality of life of people in the city.

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