

Spatial Temporal Analysis of Land Surface Temperature Changes in Ambon Island from Landsat 8 Image Data Using Google Earth Engine

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ABSTRACT

This study aims to analyze land surface temperature changes on Ambon Island using Landsat 8 imagery data and Google Earth Engine. The research method involves the use of Ambon Island boundary data from the Geospatial Information Agency (BIG) as well as Landsat 8 Collection 2 Tier 1 and Real-Time satellite image data that have been calibrated to reflect the reflectance of the Earth's surface to the atmosphere. The analysis steps include temperature conversion from Kelvin to Celsius, land surface temperature classification, and data export to Arc GIS software. The results showed an increase in land surface temperature associated with urban development in Ambon City, highlighting the importance of sustainable urban planning and good resource management to mitigate the negative impacts of land surface temperature increase and support adaptation to climate change.

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1. INTRODUCTION

Rising land surface temperatures are caused by global warming, a phenomenon characterized by an increase in the average temperature of the Earth's surface [1]. Global warming is triggered by an increase in the concentration of greenhouse gases in the atmosphere, including carbon dioxide, methane, and ozone, which block solar heat from the earth and retain heat in the atmosphere [2]. The total consumption of fossil fuels in the world is increasing by 1 percent per year, which contributes to this increase in greenhouse gas emissions. Significant impacts of global warming include extreme climate change, such as an increase in the frequency and intensity of extreme weather such as floods, storms, and forest fires [3]. In addition, this climate change also affects the migration of animals and plants, which seek cooler or cooler habitats as temperatures in their natural habitat become too warm [4].

Rising land surface temperatures in Indonesia have become a serious concern, especially in the West-Central region of Indonesia. The Meteorology, Climatology and Geophysics Agency (BMKG) has warned of a marked increase in surface temperatures in the region. This indicates that climate change and global warming have a direct impact on weather and environmental conditions in Indonesia, including the potential for increased risk of natural disasters such as landslides and flash floods, as well as changes in rainfall patterns that can affect people's lives and local ecosystems [5]. BMKG has also identified several areas in Indonesia that have the potential to experience extreme weather, including heavy rains, which can affect community activities and infrastructure. In addition, BMKG also warned of potential landslides and flash floods in several

areas after the earthquake in Garut, indicating that changes in surface temperature and unstable weather conditions can exacerbate the risk of natural disasters [6].

The increase in land surface temperature on Ambon Island is a significant phenomenon that needs attention [7], [8]. Ambon Island, as part of Indonesia, is experiencing climate change that has an impact on its land surface temperature. These changes are not only caused by natural factors such as plate movements or volcanic activity, but also by the increasingly evident global climate change. Global warming and climate change have caused an increase in average temperatures around the world, including in tropical regions such as Maluku [9]. From a social and economic perspective, the increase in land surface temperature in Ambon City also has significant implications. In longer and warmer summers, people may experience difficulties in maintaining their health and living comfort. In addition, increasing temperatures can also affect economic sectors such as agriculture and fisheries, which are critical to the local economy. Climate change can disrupt crop growth patterns and crop quality, as well as alter fish migration patterns, all of which have the potential to undermine the economic sustainability of communities. Overall, the increase in land surface temperature in Ambon City is a concrete example of the increasingly apparent impacts of climate change and the urgent need for appropriate mitigation and adaptation efforts to deal with it [10], [11].

Google Earth Engine is a cloud-based platform designed for the analysis and visualization of geospatial datasets, aimed at academic, non-profit, business, and government users. The platform stores satellite imagery and geospatial data in a public archive that includes historical earth images going back more than forty years [12],[13]. The images are captured daily and then made available for global-scale data mining. In addition, Earth Engine also provides APIs and other tools to facilitate the analysis of large datasets. Google Earth Engine (GEE) provides a powerful platform to conduct spatial-temporal analysis of land surface temperature changes in Ambon Island using Landsat 8 imagery data [14]. GEE allows users to access and analyze satellite image data efficiently and effectively, utilizing cloud computing technology to process and analyze data on a large scale without requiring a computer with high specifications [11]. To conduct the analysis, researchers used JavaScript or Python code in GEE to access the Landsat 8 image collection, calculate land surface temperature, and analyze spatial and temporal temperature changes in 2018 and 2024.

Based on the description above, this research aims to dynamics of land surface temperature changes that occur in Ambon City in 2018 and 2024. Spatial temporal analysis of land surface temperature changes in Ambon Island using Landsat 8 image data through Google Earth Engine based on cloud computing provides significant benefits in understanding and responding to climate change. By efficiently and effectively accessing and analyzing satellite imagery data, this analysis enables researchers and decision-makers to gain in-depth insights into how changes in land surface temperature affect local ecosystems, the water cycle, and the lives of local communities. The results of this analysis can be used to support decision-making in sectors such as agricultural development, water resource management and disaster management, as well as assist in the identification of areas most vulnerable to climate change and design effective adaptation strategies.

2. METHOD

This research was conducted in Ambon Island, Maluku Province, Indonesia. This research uses Ambon Island boundary data obtained from the Geospatial Information Agency (BIG) and Landsat 8 Collection 2 Tier 1 and Real-Time satellite image data set calibrated top-of-atmosphere (TOA) reflectance in 2018 and 2024 in Geogle Earth Engine (GEE): <https://code.earthengine.google.com/>. Landsat 8 Collection 2 Tier 1 and Real-Time calibrated top-of-atmosphere (TOA) satellite imagery is imagery data that has been calibrated to reflect reflectance from the Earth's surface to the atmosphere, without influence from the atmosphere. It is extracted from the image metadata and includes calibrated reflectance for all image bands, including the thermal infrared band. Landsat 8 Collection 2 Tier 1 offers the highest data quality available and is suitable for time-process analysis, with consistent georegistration and within specified tolerances. In addition, the collection also includes Real-Time (RT) assets containing newly received and processed Landsat 7 ETM+ and Landsat 8 OLI/TIRS data, but still using predicted ephemeris, initial bumper mode parameters, or initial TIRS line-of-sight models. Once the data has been reprocessed with definitive ephemeris, updated mode bumper parameters, and smoothed TIRS parameters, the product will be moved to Tier 1 or Tier 2 and removed from the Real-Time tier. This transition usually takes between 14 to 26 days. The analysis of land surface temperature in Ternate Tengah sub-district was carried out in the period January 1, 2018-December 31, 2018 and the period January 1, 2024-May 1, 2024. The research workflow can be seen in Figure 1.

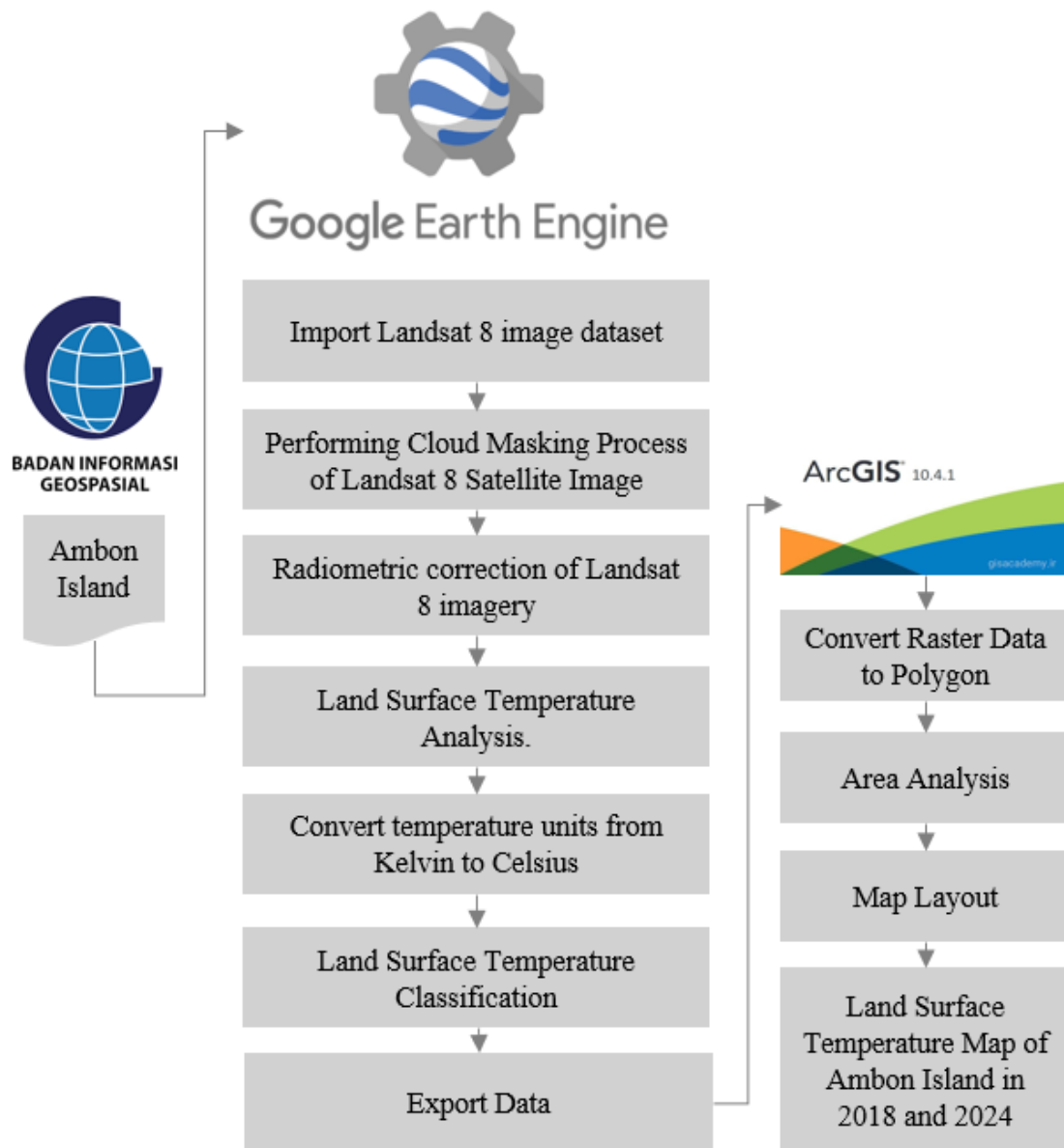


Figure 1. Workflow

This research begins by preparing data for the Ambon Island area that is loaded from the Geospatial Information Agency (BIG) website and creating a Google Earth Engine (GEE) account and preparing a script for processing land surface temperature. The initial step taken is to import the Landsat 8 image, after that cloud masking is a process to detect clouds, cloud masking is done to remove clouds and cloud shadows that interfere with the area to be processed, after that make radiometric correction of the Landsat 8 image which aims to eliminate atmospheric effects on the image, so as to produce more accurate data and can be used for more in-depth analysis. This radiometric correction is done by converting the digital number (DN) value into a surface reflectance value or surface temperature, which allows researchers to understand the physical characteristics of objects seen in the image without distortion caused by the atmosphere [15]. The next step is to analyze the land surface temperature using the "Single Channel Algorithm" or "Split-Window Algorithm". This formula converts the radiance value of the brightness temperature in band 10 into the surface temperature [16].

To analyze land surface temperature (LST) in Landsat 8 imagery using Google Earth Engine (GEE) based on cloud computing, the formula used is "Single Channel Algorithm" or "Split-Window Algorithm". This formula converts the radiance value of the brightness temperature in band 10 into the surface temperature. This formula assumes that the surface temperature (T_b) can be calculated from the radiance in band 10 (B10) of Landsat 8 imagery, using a radiometric correction factor adjusted to access the true surface temperature. This correction factor considers atmospheric effects and the spectral characteristics of the land surface. This

formula enables a more accurate and in-depth analysis of land surface temperature, which is important for a variety of applications, including climate research, water resource management and disaster management. The next step is to convert Kelvin surface temperature to degrees (°C). Converting the land surface temperature from Kelvin to Degree Celsius (°C) is essential to facilitate the interpretation of the results of land surface temperature analysis from satellite images such as Landsat 8. This conversion is done because Kelvin is an absolute temperature scale, while Celsius is a relative scale that is easier to understand and use in everyday life [1]. To convert the temperature from Kelvin to Celsius, by subtracting 273.15 from the temperature value in Kelvin [17], after that the land surface temperature in Degrees Celsius (°C) is classified into four classes, then exported to Arc GIS software, the raster data is then converted into polygon data to facilitate area analysis.

3. RESULTS AND DISCUSSION

3.1. Land Surface Temperature of Ambon Island in 2018

The results of cloud computing-based land surface temperature analysis in Google Earth Engine for Ambon Island in 2018 show significant temperature variations across the island. Using Landsat 8 imagery data and a suitable algorithm, this study was able to identify the distribution of annual average land surface temperatures, which ranged from a low of about 11°C to a high of about 28°C. This temperature variation reflects the difference between the dry and wet seasons, as well as the influence of topography and vegetation on surface temperature. Based on the results of the analysis, the land surface temperature of Ambon Island in 2018 was then classified into four temperature classes, which include: (1) Areas with land surface temperature < 15 °C: 43.65 ha or 0.06% of the total area of Ambon Island. These areas are located in higher areas or have denser vegetation that is able to absorb heat efficiently. (2) Areas with land surface temperatures of 15-20°C cover 25,772.55 ha or 33.42% of the total area of Ambon Island. These areas may be located in lower areas or have less dense vegetation, allowing heat radiation to more easily reach the ground surface. (3) Areas with land surface temperatures of 20-25°C cover 50,365.63 ha or 65.31% of the total area of Ambon Island. These areas may be located in areas that have a balance between vegetation and topography, allowing the land surface temperature to stabilize. (4) Areas with land surface temperature > 25°C are 938.51 ha or 1.22% of the total area of Ambon Island. These areas may be located in areas that are lower or directly exposed to solar heat radiation, such as beaches or areas with less vegetation. This analysis shows that Ambon Island experiences significant land surface temperature changes throughout the year, which can affect local ecosystems, the water cycle, and people's lives. This knowledge is important to support decision-making in various sectors, including agricultural development, water resources management, and disaster management. In addition, the results of this study can also be used as a basis for further research on climate change and adaptation to such changes on Ambon Island. The land surface temperature of Ambon Island in 2018 can be seen in Figure 2.

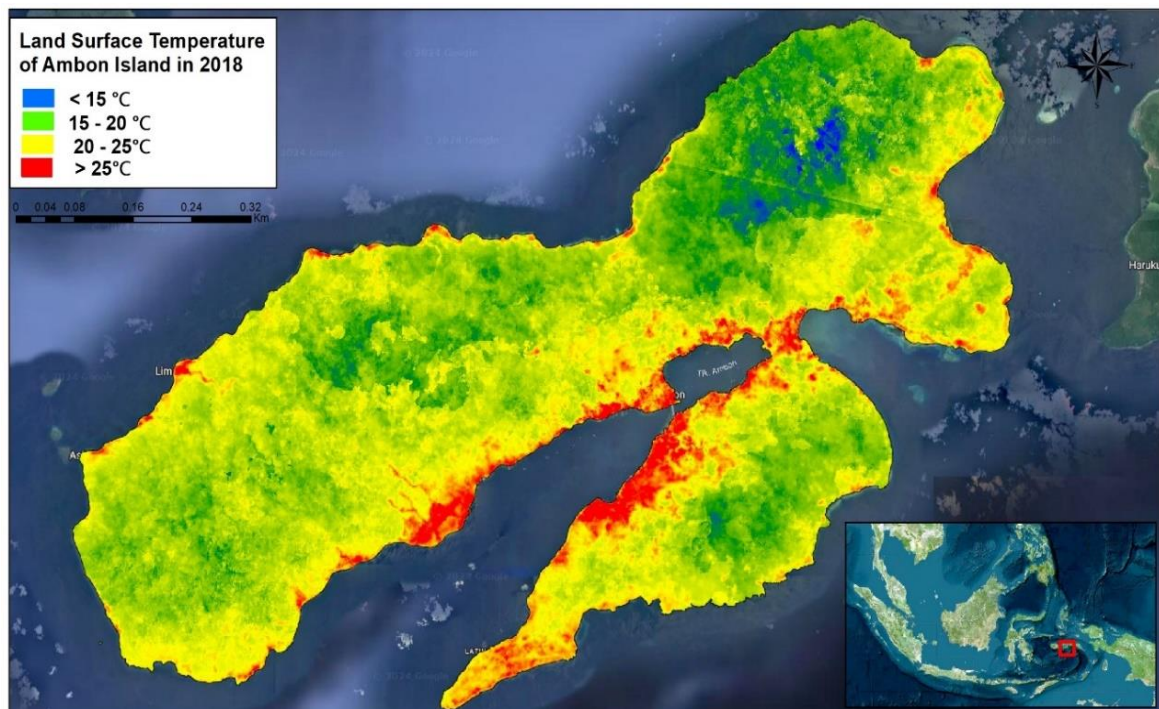


Figure 2. Land Surface Temperature of Ambon Island in 2018

Urban development in Ambon City, as in many other cities, is often closely linked to increases in land surface temperature. Rapid and uncontrolled urban growth can change land cover and land use, such as the replacement of forests and open land with buildings and infrastructure, which in turn can increase albedo (the ability of a surface to reflect sunlight) and reduce vegetation that functions as a heat sink. This can result in an increase in land surface temperature, a phenomenon known as the air effect. In addition, human activities such as infrastructure development, energy use, and greenhouse gas emissions can also contribute to increasing global temperatures, which in turn affect land surface temperatures in cities such as Ambon City. Therefore, sustainable and environmentally balanced urban planning is crucial to mitigate the negative impacts of urban development on land surface temperature and the climate as a whole.

3.2. Land Surface Temperature of Ambon Island in 2024

The results of cloud computing-based land surface temperature analysis in Google Earth Engine for Ambon Island in 2024 show an increase in temperature variability compared to 2018 data. With a low temperature of about 8°C and a high temperature of about 30°C, these results indicate that Ambon Island has experienced significant climate change in recent years. These temperature variations reflect differences between the dry and wet seasons, as well as the influence of topography and vegetation on surface temperature. Based on the results of the analysis, the land surface temperature of Ambon Island in 2024 in Figure 3. is then classified into four temperature classes, which include: (1) Areas with land surface temperature < 15°C covering 678.88 ha or 0.87% of the total area of Ambon Island. These areas may be located in higher areas or have denser vegetation that is able to absorb heat efficiently. (2) Areas with land surface temperatures of 15-20°C cover 28,588.09 ha or 59.32% of the total area of Ambon Island. These areas may be located in lower areas or have less dense vegetation, allowing heat radiation to more easily reach the ground surface. (3) Areas with land surface temperatures of 20-25°C cover 45,750.26 ha or 59.32% of the total area of Ambon Island. These areas may be located in areas that have a balance between vegetation and topography, allowing the land surface temperature to stabilize. (4) Areas with land surface temperature > 25°C are 2,107.71 ha or 2.73% of the total area of Ambon Island. These areas may be located in areas that are lower or directly exposed to solar heat radiation, such as beaches or areas with less vegetation. These changes indicate that Ambon Island is experiencing significant climate change, which may affect local ecosystems, the water cycle, and people's lives. This knowledge is important to support decision-making in various sectors, including agricultural sector development, water resource management, and disaster management.

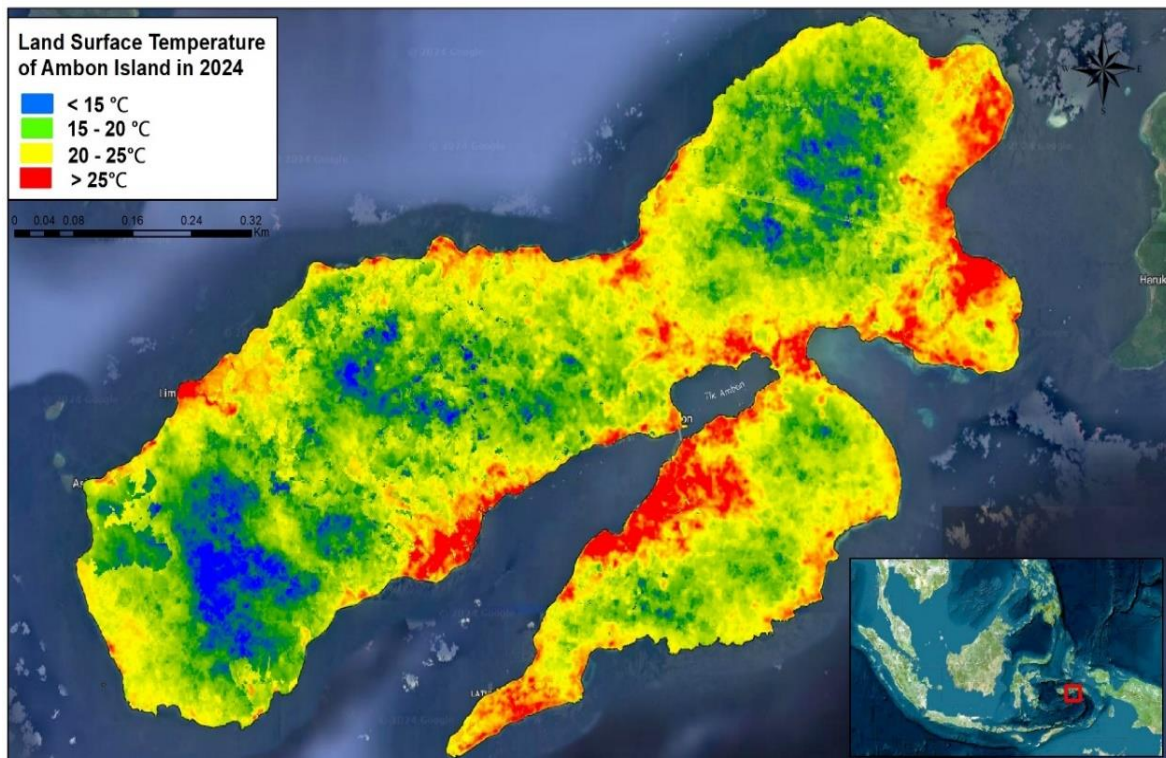


Figure 3. Land Surface Temperature of Ambon Island in 2024

Spatial-temporal analysis of land surface temperature changes on Ambon Island from Landsat 8 image data using Google Earth Engine based on cloud computing offers important benefits in various aspects, especially in the context of climate research and natural resource management. First, this method allows researchers to access and analyze satellite image data efficiently and effectively, which is crucial for understanding the dynamics of climate change in the region [18], [19]. Second, this analysis can provide insights into how changes in land surface temperature relate to environmental factors such as vegetation, soil type and human activities, which is important for decision-making related to climate change mitigation and natural disaster management [20], [14]. Third, the results of this analysis can be used by governments and non-governmental organizations to plan adaptation strategies to climate change and optimize the use of natural resources. Fourth, this method also supports further research on climate change and its impact on ecosystems and people's lives on Ambon Island [21],[22].

Infrastructure development and increased human activity in cities can increase the amount of surfaces directly exposed to solar radiation, which in turn can increase land surface temperatures [23]. Unsustainable development and inappropriate land use can reduce vegetation and add heat-absorbing materials, such as concrete and asphalt, which can affect surface temperatures [24]. Increases in land surface temperature can affect the water cycle and air quality in cities, which in turn can affect the health and comfort of residents [25], [26]. Therefore, sustainable urban planning and good resource management are essential to mitigate the negative impacts of increasing land surface temperature and support adaptation to climate change.

4. CONCLUSION

It can be concluded that the spatial-temporal analysis of land surface temperature changes on Ambon Island using Landsat 8 image data through Google Earth Engine based on cloud computing provides deep insight into the dynamics of land surface temperature changes in the region. The analysis shows an increase in temperature variability from 2018 to 2024, which can be attributed to rapid and uncontrolled urban growth and human activities that contribute to climate change. The implications of this increase in land surface temperature emphasize the importance of sustainable and environmentally balanced urban planning to mitigate its negative impacts and support adaptation to climate change on Ambon Island. This research provides a solid basis for decision-making in sectors such as agricultural development, water resource management and disaster management, and highlights the need for effective action to meet the challenges of climate change in the future.

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