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ANALYSIS OF SURFACE TEMPERATURE IN BURU DISTRICT USING CLOUD COMPUTING ON GOOGLE EARTH ENGINE

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ABSTRACT

Monitoring land surface temperature in Buru Regency using Google Earth Engine cloud computing-based geospatial technology can help in understanding global climate and weather change, as well as provide important information for scientists, governments, and non-governmental organizations in making decisions related to climate change mitigation and natural disaster management. This research aims to analyze land surface temperature in Buru Regency using MODIS satellite image data based on the cloud computing google earth engine. This research uses Moderate Resolution Imaging Spectroradiometer (MODIS) Terra Land Surface Temperature and Emissivity 8-Day Global image data analyzed on Google Earth Engine. The results show that the lowest land surface temperature value in Buru Regency is 12, 7438° C, and the highest value is 31, 9582° C. The area that has a land surface temperature (LST) in the very high class has an area of 96,604.46 ha or 19.90%, the LST area in the high class is 139,606.47 ha or 28.76%, the LST area in the medium class is 140,853.38 ha or 29.02%, the LST area in the low class is 79,896.56 ha or 16.46% and the LST area in the very low class is 28,458.57 ha or 5.86%. The land surface temperature analysis in Buru Regency can provide important information for the local government in making policies and planning for sustainable regional development.

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Keywords: Buru, GEE, Land Surface Temperature.

INTRODUCTION

Land surface temperature is one of the important parameters in weather, climate, and environmental studies (Kanga et al., 2022). It refers to the temperature of the air measured at a height of about 1.5 meters above the ground or the surface of other objects on land. Land surface temperature is influenced by various factors, such as air temperature, solar radiation, air humidity, the type of soil or surface of objects on the land, and geographical location (Caballero et al., 2022; Tariq et al., 2023).

Changes in land surface temperature have a major impact on the environment and human life (Hu et al., 2023). Climate change and rising land surface temperatures caused by human activities, such as deforestation and greenhouse gas emissions, can impact ecosystem balance, human health, and crop and livestock production (Rakuasa, 2022). Changes in land surface temperature have a major impact on the environment and human life. According to (Ermida et al., 2020), some of the factors causing the increase in land surface temperature include; global climate change, land use change, increased greenhouse gas

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emissions, the heat island effect as well as natural variability.

According to Zulkarnain, (2016) and Khan et al., (2022), land use changes such as deforestation: conversion of forest to plantations or agriculture, and urbanization can lead to increased surface temperatures. Deforestation reduces the number of natural heat sinks such as trees and moist soils, while urban land use can increase the concentration of heat-generating materials such as asphalt and concrete. Khan et al., (2022), added that increased emissions of greenhouse gases such as carbon dioxide, methane, and others can lead to increased land surface temperatures. These gas emissions can come from various sources such as transportation, industry, and the energy sector (R. Wang et al., 2019). The heat island effect occurs when urban areas have higher surface temperatures than rural areas. This is due to a higher concentration of buildings and asphalt, as well as a reduction in green space (Diksha et al., 2023). Natural variability in the climate system such as ENSO (El Nino - Southern Oscillation) and IOD (Indian Ocean Dipole) can cause an increase in land surface temperature in some areas (Kafy et al., 2020).

The transmigration program on Buru Island is one of the Indonesian government programs that aims to move people from densely populated areas to areas that still have the potential for vacant land or minimal population, such as Buru Island. The transmigration program on Buru Island can certainly have an impact on increasing land surface temperature in the area. This is related to the land use changes made in the transmigration program. Transmigration on Buru Island involves the conversion of forest land and traditional agricultural land into modern agricultural land or plantations. Such land use changes can lead to an increase in land surface temperature because modern agricultural land or plantations have a lower albedo compared to forest land or traditional agricultural land (Zhang et al., 2023).

The growth and increase in the area of built-up land on Buru Island certainly has an impact on increasing surface temperature. Built-up land is an area used for settlement, industry, agriculture or other human activities (Tariq et al., 2023). Land clearing and land use change can alter the albedo of the Earth's surface, which is the ability of the Earth's surface to reflect sunlight. Built-up land tends to have a lower albedo compared to unaltered land, such as forests or grasslands (Maulana & Bioresita, 2023). This causes built-up land to absorb more heat from the sun, which can increase land surface temperatures (Gadekar et al., 2023).

According to Diksha et al., (2023), high surface temperature values are obtained in buildings with high density, a high proportion of impervious surfaces, and in areas where heat removal due to advection and radiation loss is inhibited, such as in urban cores with tall buildings. Significant increases in surface temperature values can have adverse socio-economic and environmental impacts on urban residents such as increased water use, energy spent on air conditioning, and health risks caused by pollution (R. Wang et al., 2019).

One of the causes of the forest fires that have occurred on Buru Island in the last ten years is the long dry season and increasing land surface temperatures (Ruzady Adjis, 2022). Increased land surface temperature is said to affect forest fires because higher temperatures can make conditions drier and increase the risk of fire (Stoyanova et al., 2022). As temperatures increase, air humidity decreases and makes plants and organic matter in forests drier (Maffei et al., 2018). Drier conditions make plants more flammable and make fires more difficult to control. Rising temperatures can also increase the frequency and intensity of heat waves, which can increase the risk of forest fires (Maffei et al., 2018). Monitoring land surface temperature in Buru Regency using Google Earth Engine cloud computing-based geospatial technology can assist in understanding global climate and weather change, and provide important information for scientists, governments, and non-governmental organizations in making decisions related to climate change mitigation and natural disaster management (Khan et al., 2022).

Google Earth Engine is a cloud computing platform for geospatial data analysis and mapping that allows users to access and analyze satellite imagery data from various sources, including Landsat, Sentinel, and MODIS (Zhengming Wan, 2020). Google Earth Engine offers programming capabilities with JavaScript and Python, as well as data visualization and analysis tools such as time series, image segmentation, and spatial analysis (NASA, 2022). In addition, the platform provides access to data that has already been processed and stored on Google's servers, which allows users to perform complex analysis on huge amounts of data (Gorelick et al., 2017). Google Earth Engine is used by scientists, governments, and non-governmental organizations to monitor environmental changes such as deforestation, climate change, and pollution, as well as to map natural resources, plant health, and weather patterns. The platform also helps in natural disaster monitoring and disaster risk mitigation.

According to R. Wang et al., (2019), Google Earth Engine can be used to analyze land surface temperature by utilizing satellite imagery data available on the platform. This data can be used to observe changes in land surface temperature over time, as well as identify distinct temperature patterns in specific regions. To conduct land surface temperature analysis, users can utilize satellite imagery data such as Landsat, Sentinel, or MODIS available on Google Earth Engine (Kanga et al., 2022). By utilizing data visualization and analysis tools, users can easily generate land surface temperature maps and compare temperature changes over time (Ermida et al., 2020).

In addition, users can also use spatial analysis tools to identify areas that have higher or lower than average land surface temperatures, as well as look at the relationship between land surface temperatures and other environmental factors such as air humidity, rainfall, and soil type (M. Wang et al., 2020). In the analysis of land surface temperature, Google Earth Engine can help in understanding global climate change and weather, and provide important information for scientists, governments, and non-governmental organizations in making decisions related to climate change mitigation and natural disaster management (M. Wang et al., 2020).

MODIS (Moderate Resolution Imaging Spectroradiometer) imagery is satellite imagery produced by the MODIS instrument mounted on NASA's Terra and Aqua satellites. The instrument is designed to obtain data on surface temperatures, vegetation, and atmospheric conditions around the world (Ermida et al., 2020). Google Earth Engine also provides access to MODIS imagery that can be used for various applications, such as land surface temperature analysis and vegetation monitoring (Ermida et al., 2020). According to Zhengming Wan, (2020), MODIS imagery can be utilized for land surface temperature analysis because this instrument can produce land surface temperature data on a global scale with good spatial resolution. Ermida et al., (2020), added that in land surface temperature analysis, MODIS images are used to obtain land surface temperature data at various locations around the world at a certain time. By using image processing algorithms, temperature data obtained from MODIS images can be used to produce land surface temperature maps.

There have been many previous researchers who have conducted research on this such as Hardyanti, L., Sobirin, S., & Wibowo, (2017), who conducted research on spatial temporal variations in land surface temperature in the city of Jakarta in 2015 and 2016, Wachid & Tyas, (2022) on NDVI transformation analysis and its relationship with LST using cloud-based platforms: Google Earth Engine in Semarang City, R. Wang et al., (2019), on detecting multi-temporal land cover change and land surface temperature in Pearl River Delta by adopting local climate zone and Khan et al., (2022), on monitoring land use land cover changes and its impacts on land surface temperature over Mardan and Charsadda Districts, Khyber Pakhtunkhwa (KP), Pakistan. This research is the first research in Maluku Province on land surface temperature analysis using Google Earth Engine.

This research provides an overview of the land surface temperature of Buru Regency in 2023 which can help in predicting natural disasters such as forest fires and floods. This research also reconstructs the initial paradigm of land surface temperature which has a negative impact on environmental damage and living things so that the results of this research can be utilized as preventive measures that can be taken as a risk reduction effort, and the results of this research will be recommended to the government or staholkder in the region in facilitating policy making and regulations related to spatial planning, land control in the future. Based on the description above, this research aims to analyze surface temperature in Buru Regency using cloud computing on the Google Earth engine.

LITERATURE REVIEW

Analysis of Surface Temperature

Surface temperature analysis plays a crucial role in understanding and monitoring the Earth's climate system (Amani, Ghorbanian, et al., 2020). Cloud computing on platforms like Google Earth Engine has revolutionized this field by providing researchers with powerful tools and access to extensive datasets (Peng et al., 2020). One key aspect of surface temperature analysis is data access, where Google Earth Engine offers a wide range of satellite imagery and climate datasets, including thermal infrared data from sensors like MODIS and Landsat.

These datasets provide valuable information on surface temperature at different spatial and temporal resolutions, allowing for comprehensive analysis. To ensure accurate and reliable results, data preprocessing is a critical step (Mo et al., 2021). Google Earth Engine facilitates this by providing tools for atmospheric correction, image compositing, and data fusion. These preprocessing tasks help remove atmospheric interference, combine multiple images for better quality, and ensure data consistency. By taking care of these steps, researchers can focus on the core analysis of surface temperature.

Once the data is prepared, Google Earth Engine empowers researchers to visualize and analyze surface temperature data effectively. The platform offers powerful visualization capabilities, allowing users to create custom visualizations, adjust parameters like color palettes, and overlay additional layers of information, such as land cover or topography (Peng et al., 2020). This enables researchers to explore spatial patterns, identify temperature anomalies, and understand the dynamics of surface temperature across different regions and time periods.

Furthermore, Google Earth Engine's computational capabilities facilitate spatial and temporal analysis of surface temperature. Researchers can calculate statistical metrics like mean, maximum, minimum, and standard deviation at various spatial scales, ranging from global to local. Temporal analysis can reveal trends, seasonal patterns, and anomalies, providing insights into climate dynamics and long-term changes. By integrating surface temperature data with other datasets, such as vegetation indices or socio-economic information, researchers can gain a deeper understanding of the relationships and impacts of surface temperature on various environmental factors. This integration enhances the analysis and allows for a more comprehensive assessment of the drivers and consequences of temperature changes.

Cloud Computing on Google Earth Engine

Cloud computing on Google Earth Engine has revolutionized the way surface temperature analysis is conducted (Amani, Kakooei, et al., 2020). With access to an extensive collection of satellite imagery and climate datasets, researchers can explore and understand surface temperature patterns with unprecedented ease. The platform provides powerful tools for data preprocessing, including atmospheric correction and image compositing, ensuring accurate and consistent results. Once the data is prepared, Google Earth Engine enables researchers to visualize surface temperature data in a compelling and intuitive manner. Custom visualizations can be created, allowing users to identify spatial patterns, detect anomalies, and explore temporal trends.

The platform's computational capabilities empower researchers to perform complex spatial and temporal analyses, calculating statistical metrics and conducting change detection studies (Laipelt et al., 2021; Tariq & Shu, 2020). Integration with other datasets, such as vegetation indices or socio-economic data, further enhances the analysis by exploring relationships between surface temperature and various environmental factors. The collaborative nature of Google Earth Engine facilitates knowledge sharing among researchers, policymakers, and the general public, fostering a deeper understanding of surface temperature dynamics and their implications for various applications. Overall, cloud computing on Google Earth Engine has democratized surface temperature analysis, making it more accessible and enabling researchers to gain valuable insights for climate studies, urban planning, agriculture, and natural resource management.

METHODS

This research was conducted in Buru Regency, Maluku Province. Administratively, Buru Regency consists of Air Buaya sub-district, Fena Leisela sub-district, Lolong Guba sub-district, Waplau sub-district, Waepo sub-district, Liliay sub-district, Namlea sub-district, Waelata sub-district, Teluk Kayeli sub-district and Batubual sub-district. This research uses Moderate Resolution Imaging Spectroradiometer (MODIS) Terra Land Surface Temperature and Emissivity 8-Day Global image data accessed and analyzed on Google Earth Engine (https://earthengine.google.com/).

MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1 km in Figure 2 is a satellite imagery product developed by NASA (Zhengming Wan, 2020). It provides information on land surface temperature and emissivity around the world with a spatial resolution of 1 kilometer. This data is generated by the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument mounted on the Terra satellite. MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1km is very useful in various applications such as surface temperature monitoring, forest fire detection, water resource management, and weather modeling (NASA, 2022).

Analysis of land surface temperature in Buru Regency was conducted in the period 01-01-2023 - 01-04-2023. The surface temperature analysis in this study was conducted on the Google Earth Engine (GEE) cloud computing platform which can be accessed at https://earthengine.google.com/. The spatial location of the study can be seen in **Figure 1**.

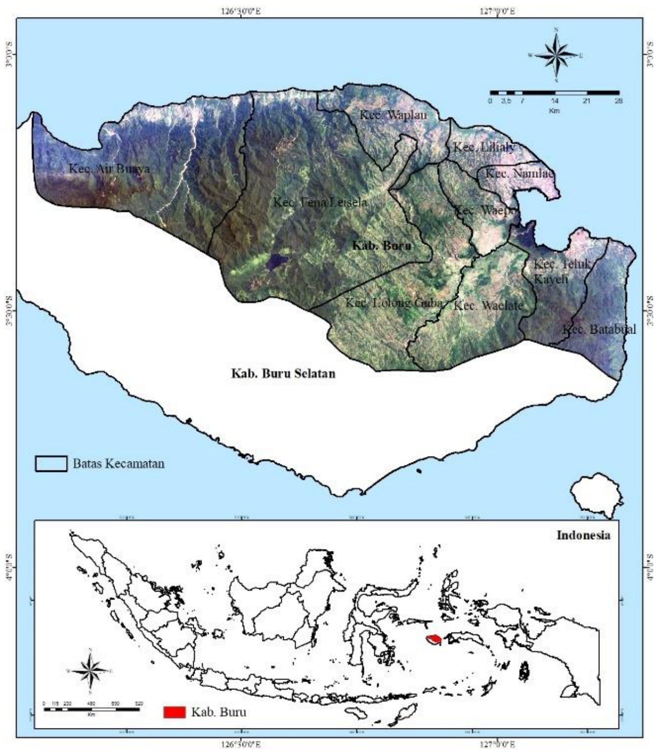

Figure 1 Research Location

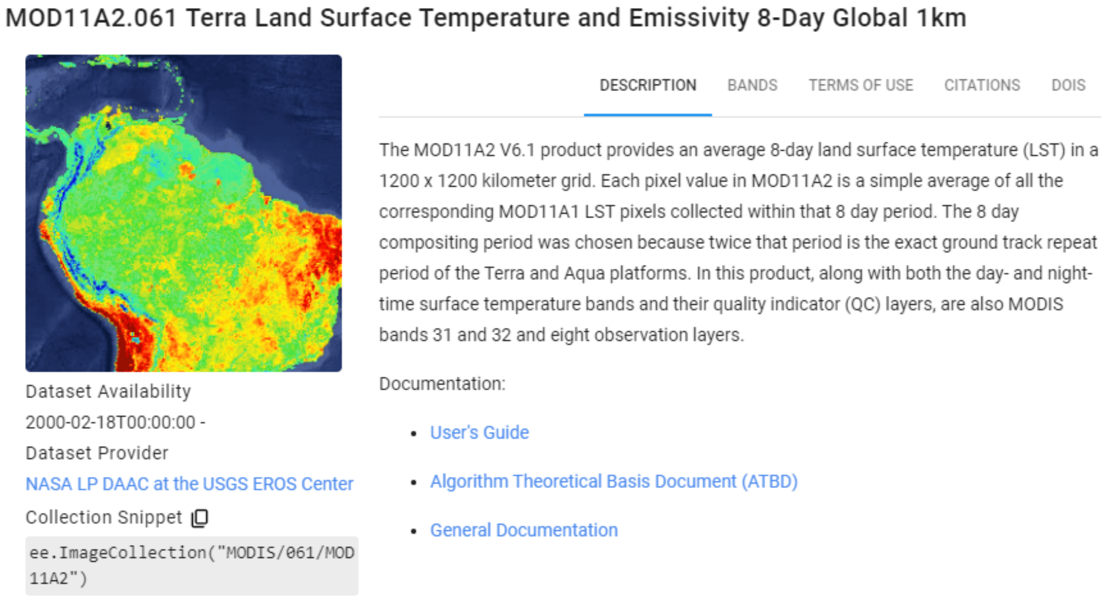

Figure 2 MODIS Image Dataset View

MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1km in **Figure 2** is a satellite imagery product developed by NASA (NASA, 2022). It provides information on land surface temperature and emissivity around the world with a spatial resolution of 1 kilometer. This data is generated by the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument mounted on the Terra satellite. MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1km is very useful in various applications such as surface temperature monitoring, forest fire detection, water resource management, and weather modeling (Rakuasa, 2022). The use of the MODIS satellite for temperature detection on satellite sensors uses the Split Window Algorithm (SWA) algorithm (Zhengming Wan, 2020). How Jin Aik et al., (2021), stated that brightness temperature is one of the variables in the thermal band. The equation used for temperature detection is as follows (Equation 1):

$$T = f(x) = \frac{K2}{\text{In}\left(\frac{K1}{L\lambda} + 1\right)} \qquad (1)$$

Description:
T : Radian Temperature
Lλ : Spectral Radiance
K2 : 1282.71
K1 : 666.09 (w/m2*ster*µm)

Then convert the temperature from radian to surface temperature with the following equation (Equation 2):

$$Ts = \left(\frac{TB}{1+\left(\frac{\lambda TB}{\rho}\right) In\varepsilon}\right. \qquad (2)$$

Description:
Ts: Surface temperature
ε : Emissivity
TB : Temperature Radian
λ : Emitted wavelength emitted 11.5 µm
ρ: hc/K (1.438x10-2 mK)

Cloud-based remote sensing satellite image processing has the advantage of not requiring large storage. One platform that supports cloud-based remote sensing digital image processing is Google Earth Engine (GEE). This platform provides an open source image database around the world, where the data can be accessed by users in real-time. According to Gorelick et al., (2017), GEE is a platform provided by the US Geological Survey and NOAA that can perform computing and data processing quickly. There are various functions for image processing on this platform including statistical analysis, edge detection, image bit value analysis and matrix testing (Ermida et al., 2020). Cloud-based processing of land surface temperature in Buru Regency was conducted using the Geogle Earth Engine platform. The Google Earth Engine view can be seen in **Figure 3**.

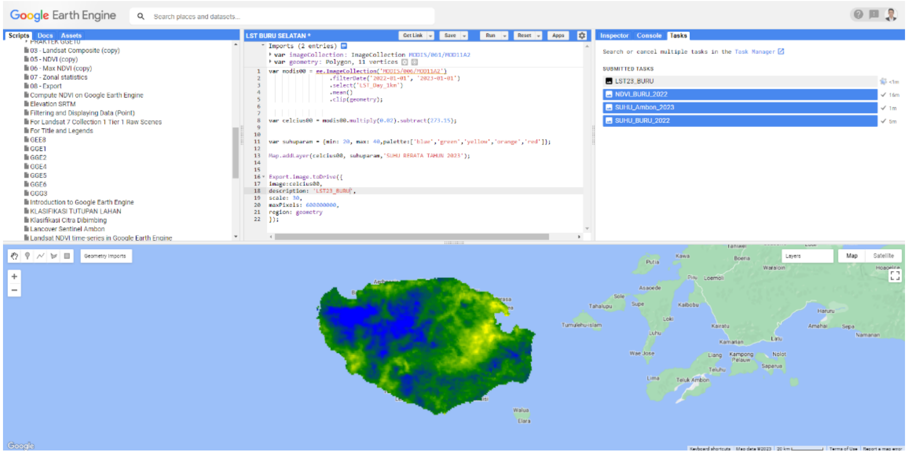

Figure 3 Google Earth Engine View

The process of data processing and analysis is entirely done with Java Script in Google Earth Engine. The stages of data processing and analysis are as follows:

1. Import Image CollectionMODIS, aims to display or call MODIS images from the GEE Catalog.

var MODIS00 = ee.ImageCollection('MODIS/006/MOD11A2')

2. Determine the time variable, aiming to determine the time span of the study.

filterDate('2023-01-01', '2023-04-01')

3. Selecting the LST Day 1 Km Band, aims to select the average pixel value of LST Day 1 Km (MOD11A2) from all MOD11A1 pixels in an 8-day period.

select('LST_Day_1km')

4. Clip according to boundaries and display data to a map, aims to process data according to the research location using the Buru Regency boundary shapefile and display it to a map.

clip(geometry);

5. Convert Kelvin to Celsius, aims to convert LST values from Kelvin to Celsius scale.

var celcius00 = MODIS00.multiply(0.02).subtract(273.15);

6. Display surface temperature or radiant emission temperature/netto on the map

var suhuparam = {min: 20, max: 40,palette:['blue','green','yellow','orange','red']};

7. Display the result of surface temperature analysis in the GEE Layer

Map.addLayer(celcius00, suhuparam,'SUHU RERATA TAHUN 2000');

8. Mexport the LST analysis results to Google Drive which can then be downloaded for further analysis in GIS software.

Export.image.toDrive({image:celcius10, description: 'SUHU_PERMUKAAN_BURU_2023', scale: 30, maxPixels: 600000000, region: geometry});

After the results of the land surface temperature analysis are uploaded from Google Drive, classification is carried out in Arc GIS software which refers to research (Sasky, P., Sobirin, S., & Wibowo, 2017). The classification of land surface temperature analysis can be seen in **Table 1**.

Table 1 Land Surface Temperature Classification

No	Land Surface Temperature Class	Description
1	Very Low	<20º C
2	Low	20º C – 25º C
3	Medium	25º C – 30º C
4	High	30º C - 35º C
5	Very High	>35º C

Source: (Sasky, P., Sobirin, S., & Wibowo, 2017)

RESULTS AND DISCUSSION

Based on the results of the Google Earth Engine Script application to process the MODIS MOD11A2.006 Terra Land Surface Temperature and Emissivity 8-Day Global1km Image, the average Land Surface Temperature distribution data of Buru Regency is obtained. Visual data on the distribution of the average Land Surface Temperature of Buru Regency in 2023 can be seen in **Figure 4**.

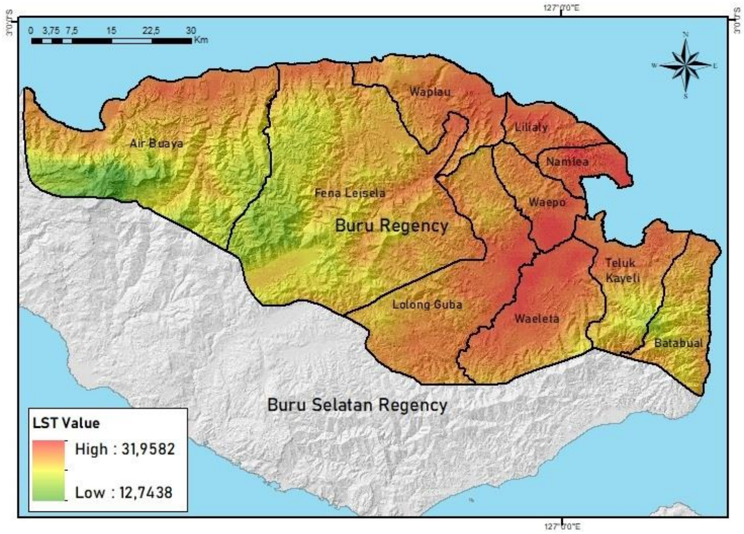

Figure 4 Land Surface Temperature Values of Buru Regency

Land surface temperature (LST) values can vary depending on various factors such as location, time of day, weather conditions as well as land use. Land surface temperature data can be obtained from satellites equipped with thermal sensors such as MODIS or Landsat. Land surface temperature values obtained from satellite data can be expressed in Kelvin, Celsius, or Fahrenheit depending on the preference of the analysis (Sasky, P., Sobirin, S., & Wibowo, 2017).

The value of land surface temperature in Buru Regency can be seen in **Figure 4** where the lowest value is 12, 7438° C and the highest value is 31, 9582° C. The value with the highest surface temperature in **Figure 4** is identified in red and the lowest value in green. The spatial map of the Land Surface Temperature class of Buru Regency can be seen in **Figure 5**.

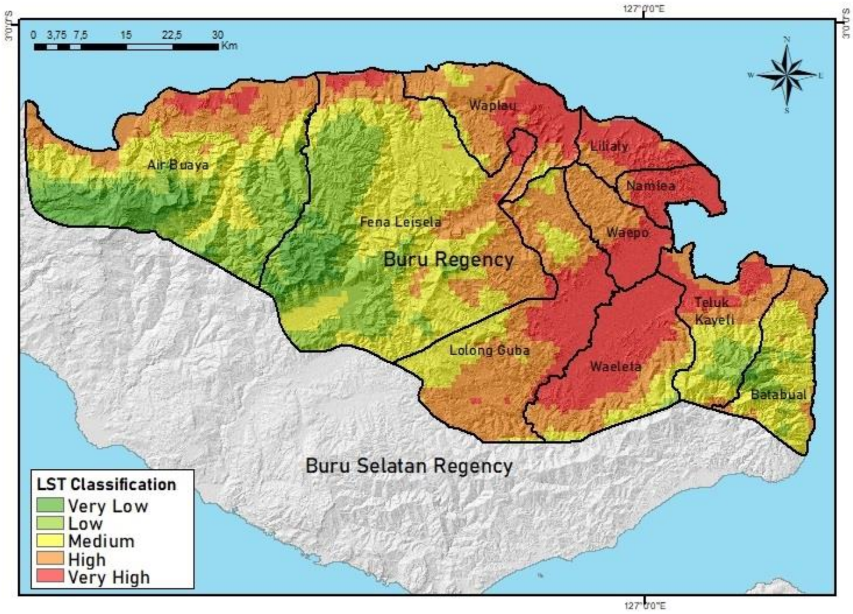

Figure 5 Land Surface Temperature Class of Buru Regency

Land Surface Temperature Class is the division of the range of land surface temperature values into several classes or categories based on certain boundaries. This division aims to facilitate data analysis and interpretation of information related to land surface temperature. In this study, the land surface temperature class is divided into four classes referring to the following research (Sasky, P., Sobirin, S., & Wibowo, 2017). **Figure 5** shows that the area of land surface temperature (LST) in the very high class has an area of 96,604.46 ha or 19.90%, the area of LST in the high class is 139,606.47 ha or 28.76%, the area of LST in the medium class is 140,853.38 ha or 29.02%, the area of LST in the low class is 79,896.56 ha or 16.46% and the area of LST in the very low class is 28,458.57 ha or 5.86%. The results of the analysis also show that surface temperature is spatially very high in the coastal areas of Buru Regency.

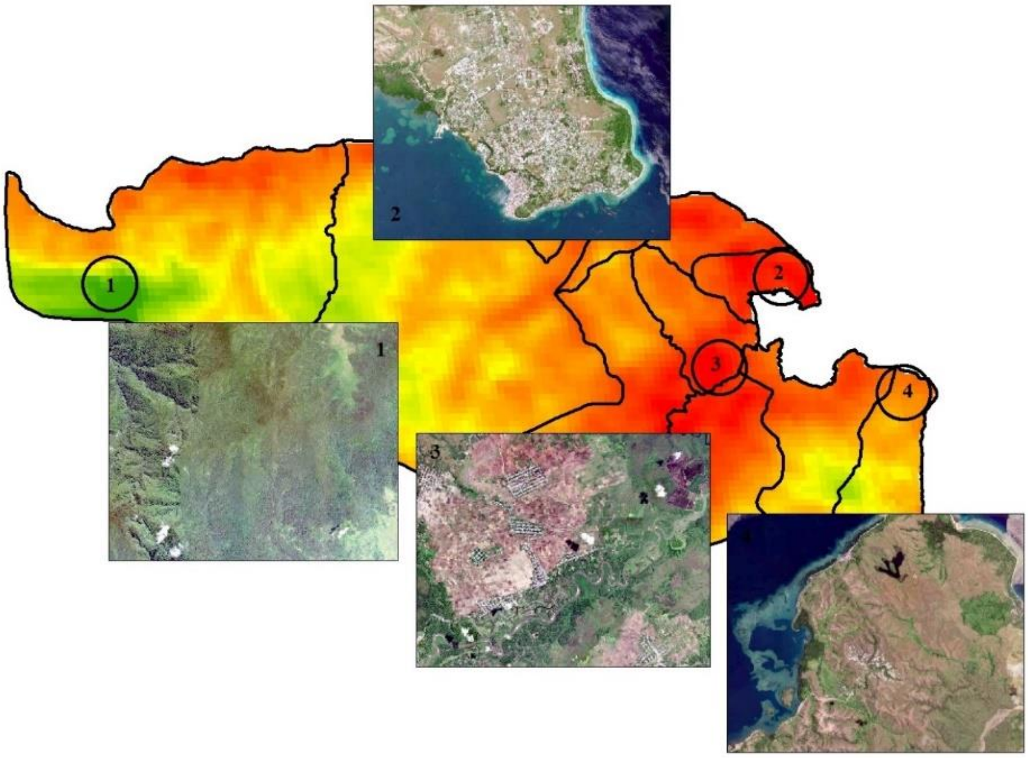

Figure 6 Relationship between Built-up Land and Surface Temperature

Figure 6 shows that areas of built-up land and open land in Buru Regency have very high surface temperature values compared to forests which have low land surface temperatures. According to Khan et al., (2022), In general, the regions that have high land surface temperatures are the tropical and subtropical regions as I mentioned earlier. Land surface temperature in an area can be influenced by factors such as climate, weather, altitude, and land cover, so it can vary in different regions. According to Khan et al., (2022), te land cover class of built-up areas or settlements and open land has a very high surface temperature compared to other types of land cover such as forests and plantations. Land surface temperature analysis has many benefits, including:

1. Weather Prediction: Land surface temperature is very important for weather prediction. Higher land surface temperatures can indicate the potential for storms or hot weather, while lower temperatures can indicate the potential for cold weather or snow.
2. Climate Analysis: Land surface temperature analysis can also provide useful information about climate and climate change. Land surface temperature data can be used to track changes in average temperatures and other climate trends.

3. Agriculture: Land surface temperature is also very important in agriculture. Temperature data can help farmers select crops that are suitable for the temperature and climate in their area. This will increase the productivity and efficiency of agricultural production.
4. Natural Resource Management: Land surface temperature data can also be used to help manage natural resources such as water, forests and agricultural land. By knowing the exact temperature, experts can predict droughts or floods that may affect water availability or soil conditions.
5. Environmental Management: Measuring land surface temperature can help in environmental management. For example, an increase in land surface temperature can affect water quality and environmental habitats which can lead to disruptions in animal and plant populations in an area.

Development Planning: Information on land surface temperature can be used in planning the development of cities and infrastructure, such as roads and buildings. By knowing the land surface temperature, experts can plan buildings that are more efficient at reducing heat and improving energy efficiency.

CONCLUSION

The results showed that the lowest land surface temperature ("LST") value in Buru Regency is 12, 7438° C while the highest value is 31, 9582° C. The area of land surface temperature (LST) in the very high class is 96,604.46 ha or 19.90%, while the area of LST in the high class is 139,606.47 ha or 28.90%. The area that has a land surface temperature (LST) in the very high class has an area of 96,604.46 ha or 19.90%, the LST area in the high grade is 139,606.47 ha or 28.76, the LST area in the medium grade is 140,853.38 ha or 29.02%, the LST area in the low grade is 79,896.56 ha or 16.46% and the LST area in the very low grade is 28,458.57 ha or 5.86%.

The analysis also shows that the surface temperature is spatially very high in the coastal areas of Buru Regency. The results of the research are expected to provide substantial benefits to the local government in planning and making decisions in various sectors including the development of the agricultural sectors, water resources management, and disaster management. Thus, the analysis of land surface temperature in Buru Regency can provide essential information for the local government in making policies and planning for sustainable regional development.

Author's declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

REFERENCES

Amani, M., Ghorbanian, A., Ahmadi, S. A., Kakooei, M., Moghimi, A., Mirmazloumi, S. M., Moghaddam, S. H. A., Mahdavi, S., Ghahremanloo, M., & Parsian, S. (2020). Google earth engine cloud computing platform for remote sensing big data applications: A comprehensive review. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *13*, 5326–5350.

Amani, M., Kakooei, M., Moghimi, A., Ghorbanian, A., Ranjgar, B., Mahdavi, S., Davidson, A., Fisette, T., Rollin, P., & Brisco, B. (2020). Application of google earth engine cloud computing platform, sentinel imagery, and neural networks for crop mapping in Canada. *Remote Sensing*, *12*(21), 3561.

Caballero, C. B., Ruhoff, A., & Biggs, T. (2022). Land use and land cover changes and their impacts on surface-atmosphere interactions in Brazil: A systematic review. *Science of The Total Environment*, *808*, 152134. https://doi.org/10.1016/j.scitotenv.2021.152134

Diksha, Kumari, M., & Kumari, R. (2023). Spatiotemporal Characterization of Land Surface Temperature in Relation

Landuse/Cover: A Spatial Autocorrelation Approach. *Journal of Landscape Ecology*. https://doi.org/10.2478/jlecol-2023-0001

Ermida, S. L., Soares, P., Mantas, V., Göttsche, F.-M., & Trigo, I. F. (2020a). Google Earth Engine Open-Source Code for Land Surface Temperature Estimation from the Landsat Series. *Remote Sensing*, *12*(9), 1471. https://doi.org/10.3390/rs12091471

Ermida, S. L., Soares, P., Mantas, V., Göttsche, F.-M., & Trigo, I. F. (2020b). Google Earth Engine Open-Source Code for Land Surface Temperature Estimation from the Landsat Series. *Remote Sensing*, *12*(9), 1471. https://doi.org/10.3390/rs12091471

Gadekar, K., Pande, C. B., Rajesh, J., Gorantiwar, S. D., & Atre, A. A. (2023). *Estimation of Land Surface Temperature and Urban Heat Island by Using Google Earth Engine and Remote Sensing Data* (pp. 367–389). https://doi.org/10.1007/978-3-031-19059-9_14

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, *202*, 18–27. https://doi.org/10.1016/j.rse.2017.06.031

Hardyanti, L., Sobirin, S., & Wibowo, A. (2017). Variasi Spasial Temporal Suhu Permukaan Daratan di Kota Jakarta tahun 2015 dan 2016. *Prosiding Industrial Research Workshop and National Seminar*, 704–713. https://doi.org/10.35313/irwns.v8i3.613

How Jin Aik, D., Ismail, M. H., Muharam, F. M., & Alias, M. A. (2021). Evaluating the impacts of land use/land cover changes across topography against land surface temperature in Cameron Highlands. *PLOS ONE*, *16*(5), e0252111. https://doi.org/10.1371/journal.pone.0252111

Hu, Y., Tang, R., Jiang, X., Li, Z.-L., Jiang, Y., Liu, M., Gao, C., & Zhou, X. (2023). A physical method for downscaling land surface temperatures using surface energy balance theory. *Remote Sensing of Environment*, *286*, 113421. https://doi.org/10.1016/j.rse.2022.113421

Kafy, A.- Al, Rahman, Md. S., Faisal, A.-A.-, Hasan, M. M., & Islam, M. (2020). Modelling future land use land cover changes and their impacts on land surface temperatures in Rajshahi, Bangladesh. *Remote Sensing Applications: Society and Environment*, *18*, 100314. https://doi.org/10.1016/j.rsase.2020.100314

Kanga, S., Meraj, G., Johnson, B. A., Singh, S. K., PV, M. N., Farooq, M., Kumar, P., Marazi, A., & Sahu, N. (2022). Understanding the Linkage between Urban Growth and Land Surface Temperature—A Case Study of Bangalore City, India. *Remote Sensing*, *14*(17). https://doi.org/10.3390/rs14174241

Khan, R., Li, H., Basir, M., Chen, Y. L., Sajjad, M. M., Haq, I. U., Ullah, B., Arif, M., & Hassan, W. (2022). Monitoring land use land cover changes and its impacts on land surface temperature over Mardan and Charsadda Districts, Khyber Pakhtunkhwa (KP), Pakistan. *Environmental Monitoring and Assessment*, *194*(6), 409. https://doi.org/10.1007/s10661-022-10072-1

Laipelt, L., Kayser, R. H. B., Fleischmann, A. S., Ruhoff, A., Bastiaanssen, W., Erickson, T. A., & Melton, F. (2021). Long-term monitoring of evapotranspiration using the SEBAL algorithm and Google Earth Engine cloud computing. *ISPRS Journal of Photogrammetry and Remote Sensing*, *178*, 81–96.

Maffei, C., Alfieri, S., & Menenti, M. (2018). Relating Spatiotemporal Patterns of Forest Fires Burned Area and Duration to Diurnal Land Surface Temperature Anomalies. *Remote Sensing*, *10*(11), 1777. https://doi.org/10.3390/rs10111777

Maulana, J., & Bioresita, F. (2023). Monitoring of Land Surface Temperature in Surabaya, Indonesia from 2013-2021 Using Landsat-8 Imagery and Google Earth Engine. *IOP Conference Series: Earth and Environmental Science*, *1127*(1), 012027. https://doi.org/10.1088/1755-1315/1127/1/012027

Mo, Y., Xu, Y., Chen, H., & Zhu, S. (2021). A review of reconstructing remotely sensed land surface temperature under cloudy conditions. *Remote Sensing*, *13*(14), 2838.

NASA. (2022). *Moderate Resolution Imaging Spectoradiometer (MODIS)*. NASA. https://modis.gsfc.nasa.gov/

Peng, X., Wu, W., Zheng, Y., Sun, J., Hu, T., & Wang, P. (2020). Correlation analysis of land surface temperature and topographic elements in Hangzhou, China. *Scientific Reports*, *10*(1), 10451.

Rakuasa, H. (2022). Analisis Spasial Temporal Suhu Permukaan Daratan/ Land Surface Temperature (Lst) Kota Ambon Berbasis Cloud Computing: Google Earth Engine. *Jurnal Ilmiah Informatika Komputer*, *27*(3), 194–205. https://doi.org/10.35760/ik.2022.v27i3.7101

Ruzady Adjis. (2022). *Hutan di Kabupaten Buru Terbakar, Angin Kencang Percepat Amukan Kobaran Api*. TERASMALUKU.COM,-AMBON. https://terasmaluku.com/headline/2022/08/11/hutan-di-kabupaten-buru-terbakar-angin-kencang-percepat-amukan-kobaran-api/

Sasky, P., Sobirin, S., & Wibowo, A. (2017). Pengaruh Perubahan Penggunaan Tanah Terhadap Suhu Permukaan Daratan Metropolitan Bandung Raya Tahun 2000–2016. *Prosiding Industrial Research Workshop and National Seminar*, 354–361. https://doi.org/10.35313/irwns.v8i3.767

Stoyanova, J. S., Georgiev, C. G., & Neytchev, P. N. (2022). Satellite Observations of Fire Activity in Relation to Biophysical Forcing Effect of Land Surface Temperature in Mediterranean Climate. *Remote Sensing*, *14*(7), 1747. https://doi.org/10.3390/rs14071747

Tariq, A., Mumtaz, F., Majeed, M., & Zeng, X. (2023). Spatio-temporal assessment of land use land cover based on trajectories and cellular automata Markov modelling and its impact on land surface temperature of Lahore district Pakistan. *Environmental Monitoring and Assessment*, *195*(1), 114. https://doi.org/10.1007/s10661-022-10738-w

Tariq, A., & Shu, H. (2020). CA-Markov chain analysis of seasonal land surface temperature and land use land cover change using optical multi-temporal satellite data of Faisalabad, Pakistan. *Remote Sensing*, *12*(20), 3402.

Wachid, N., & Tyas, W. P. (2022). Analisis Transformasi NDVI dan kaitannya dengan LST Menggunakan Platform Berbasis Cloud: Google Earth Engine. *Jurnal Planologi*, *19*(1), 60. https://doi.org/10.30659/jpsa.v19i1.20199

Wang, M., Zhang, Z., Hu, T., Wang, G., He, G., Zhang, Z., Li, H., Wu, Z., & Liu, X. (2020). An Efficient Framework for Producing Landsat-Based Land Surface Temperature Data Using Google Earth Engine. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *13*, 4689–4701. https://doi.org/10.1109/JSTARS.2020.3014586

Wang, R., Cai, M., Ren, C., Bechtel, B., Xu, Y., & Ng, E. (2019). Detecting multi-temporal land cover change and land surface temperature in Pearl River Delta by adopting local climate zone. *Urban Climate*, *28*, 100455. https://doi.org/10.1016/j.uclim.2019.100455

Zhang, M., Kafy, A.- Al, Xiao, P., Han, S., Zou, S., Saha, M., Zhang, C., & Tan, S. (2023). Impact of urban expansion on land surface temperature and carbon emissions using machine learning algorithms in Wuhan, China. *Urban Climate*, *47*, 101347. https://doi.org/10.1016/j.uclim.2022.101347

Zhengming Wan. (2020). *MOD11A2 v061 MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1 km SIN Grid*. USGS Website. https://lpdaac.usgs.gov/products/mod11a2v061/

Zulkarnain, R. C. (2016). Pengaruh Perubahan Tutupan Lahan Terhadap Perubahan Suhu Permukaan di Kota Surabaya. *Skripsi Institut Teknologi Sepuluh Nopember*, 1–306.