Cyberspace: Jurnal Pendidikan Teknologi informasi
Volume 9, Nomor 1, Maret 2025, hal. 1 - 16
ISSN 2598-2079 (print) | ISSN 2597-9671 (online)

ANALYSIS OF LAND SURFACE TEMPERATURE IN THE KRUENG ACEH WATERSHED USING GOOGLE EARTH ENGINE

Yulia Khairunnisa[1], Sri Azizah Nazhfifah[2*], Muslim Amiren[3], Saumi Syahreza[4], Muhammad Rusdi[5], Kurnia Saputra[6], Andriani Putri[7], and Kikye Martiwi Sukiakhy[8]

[1,2,3,6,7,8] Department of Informatics, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia
[4] Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia
[5] Department of Soil Science, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh, Indonesia

E-mail: [1]yulia_kh@mhs.usk.ac.id, [2]sriazizah07@usk.ac.id
[3]muslim.amiren@usk.ac.id, [4]emrusdi@usk.ac.id,
[5]ssyahreza@usk.ac.id, [6]kurnia.saputra@usk.ac.id,
[7]andrianiputri@usk.ac.id, [8]kikye.martiwi.sukiakhy@usk.ac.id
Coressponding Author: sriazizah07@usk.ac.id

Abstract

The constantly changing land surface temperature has implications for agricultural productivity and human health, therefore it is important to observe the land surface temperature to provide information about the characteristics and patterns of a region. The purpose of this research is to determine the changes and spatial patterns of land surface temperature distribution in the Krueng Aceh Watershed in 2013, 2018, and 2023. The method employed in this study involves utilizing the Google Earth Engine platform and MODIS imagery. Land surface temperature data from MODIS imagery is processed using JavaScript programming language, and the results are analyzed to obtain the distribution of land surface temperature. The study results indicate that the land surface temperature in the Krueng Aceh Watershed was 29,11°C in 2013, increase to 29,5°C in 2018, and then decreased to 29,19°C in 2023. The Krueng Aceh Watershed in 2013, 2018, and 2023 exhibits similar spatial patterns and distributions of land surface temperature, with areas in Banda Aceh City experiencing higher temperatures compared to those in Aceh Besar District, which exhibit varying temperatures.

Keywords: *Land Surface Temperature, Krueng Aceh Watershed, Google Earth Engine, MODIS Images.*

Abstrak

Suhu permukaan darat yang terus mengalami perubahan berdampak terhadap produktivitas pertanian dan kesehatan manusia, sehingga penting dilakukannya pengamatan suhu permukaan darat untuk memberikan informasi tentang karakteristik dan pola suatu wilayah. Tujuan dari penelitian ini, yaitu untuk mengetahui perubahan dan pola spasial sebaran suhu permukaan darat di Daerah Aliran Sungai (DAS) Krueng Aceh tahun 2013, 2018, dan 2023. Metode yang digunakan dalam penelitian ini melibatkan pemanfaatan pada layanan Google

Earth Engine dan citra MODIS. Data suhu permukaan darat dari citra MODIS dilakukan pengolahan menggunakan bahasa pemrograman JavaScript dan hasilnya dilakukan analisis untuk mendapatkan sebaran suhu permukaan darat. Hasil kajian menunjukkan bahwa suhu permukaan darat di DAS Krueng Aceh tahun 2013 sebesar 29,11°C, tahun 2018 mengalami peningkatan menjadi 29,5°C, dan tahun 2023 kembali menurun menjadi 29,19°C. DAS Krueng Aceh tahun 2013, 2018, dan 2023 memiliki pola spasial dan sebaran suhu permukaan darat yang cenderung sama, yaitu wilayah DAS Krueng Aceh yang berada di Kota Banda Aceh memiliki suhu yang tinggi, sementara yang berada di Kabupaten Aceh Besar memiliki suhu yang bervariasi.

Kata Kunci: *Suhu Permukaan Darat, Daerah Aliran (DAS) Krueng Aceh, Google Earth Engine, Citra MODIS*

1. Introduction

Land surface temperature (LST) is a parameter that can provide insight into environmental conditions, impacts on life, and climate change [1]. This temperature is measured at the surface of the ground or other solid objects above the ground, for example roads and buildings [2]. Many factors affect land surface temperature including atmospheric temperature, land use type, solar radiation, atmospheric humidity, and geographic position [3]. Changes in land surface temperature have a big impact on the environment and human life. Climate change and increases in land surface temperature caused by human activities, such as deforestation and greenhouse gas emissions, can impact the balance of ecosystems and human health [4]. Therefore, observations of land surface temperature are important to provide information about the characteristics and patterns of an area, including administrative areas and areas with natural boundaries.

Monitoring changes in land surface temperature can be carried out in the natural boundary of the Krueng Aceh watershed. The Krueng Aceh watershed is geographically located at 95°11'41" - 95°49'46" East Longitude and 5°3'41" - 5°38'10" North Latitude, while administratively located in the Banda Aceh City, Aceh Besar District, Pidie District, and Aceh Jaya District [5]. The climate in the Krueng Aceh watershed is classified as class B (wet) with an average annual rainfall of 1225.9 mm. The average rainy days in this area is 145 days. In the wet months (November-January) there is a trend of increasing rainfall up to 22% while in the dry months (May-August) there is a decrease in rainfall up to 26%. Meanwhile, the average annual air temperature in the Krueng Aceh watershed ranges from 25.6°C to 27.1°C [6].

The Krueng Aceh watershed has a river length of 132.50 km and an area of around 176,550.91 ha [7]. The Krueng Aceh watershed stretches from the highlands to the lowlands, covering a variety of topography and types of land use. Land use in the Krueng Aceh watershed in 2021 is dominated by Primary Dryland Forest with an area of 51,218.64 ha or 28.66%, and grassland with an area of 32,262.65 or 18.05% of the total land cover area, while settlements have an area of 12,829.24 or 7.18% [8]. This geographical condition will provide diversity of land surface temperatures throughout the Krueng Aceh watershed area, because this area crosses Banda Aceh city with a contribution of high temperature and crosses the Aceh Besar district which has a low temperature.

Monitoring spatial patterns of land surface temperature changes in the Krueng Aceh watershed can be done using technology that combines Geographic Information

Systems, remote sensing, and cloud computing, namely Google Earth Engine. Google Earth Engine is a free and open source cloud-based environmental data analysis platform. The advantages of this platform include the availability of an Application Programming Interface (API) that supports JavaScript and Python programming languages, and can also be integrated into Github [9]. 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 [10]. The data available on Google Earth Engine (GEE) actually comes from open sources or can be accessed for free. For example, data such as Landsat, Sentinel, MODIS, and others. However, the difference is that when the user accesses the data from the original source, the user needs to download it first to the computer before being able to process it. Meanwhile, in GEE, you can access this data directly, without needing to download it, and users can process it according to their analysis needs until they reach data processing purposes [11].

Google Earth Engine is a different platform from Google Earth Pro. Google Earth facilitates users to explore the earth through virtual tours and sightseeing activities. Meanwhile, Google Earth Engine gives users the ability to process imagery data from remote sensing and allows for the retrieval of spatial information relating to changes and events on the earth's surface [11]. The Google Earth Engine data repository is a collection of over 40 years of satellite imagery around the world, with many locations having two weeks of repeat data for the entire period, as well as large daily and sub-daily datasets. The accessible data is taken from a variety of satellites, including Sentinel-1, 2, and 3, the National Oceanographic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR), Landsat, Advanced Land Observing Satellite (ALOS), and the Moderate Resolution Imaging Spectrometer (MODIS). It also includes most geophysical, demographic, and climate and weather data. A complete list of available data can be obtained from the web portal earthengine.google.com/datasets/ [12].

One of the remote sensing satellite data that can be used to analyze surface temperature using Google Earth Engine service is the Moderate Resolution Imaging Spectroradiometer satellite or more easily known as the MODIS satellite. The Terra/Aqua satellite, which carries the MODIS sensor, can be utilized to collect land surface temperature (LST) data. This land surface temperature data is very important for various MODIS Land and Atmospheric products such as aerosols, land-cover, evapotranspiration, atmospheric profiles, and interdisciplinary research needs regarding EOS (Earth Observing System). Land surface temperature is also often a key input in model calculations of evapotranspiration, air humidity, soil moisture, energy balance, and others [13]. Terra MODIS and Aqua MODIS see the entire surface of the earth every 1 to 2 days, with data acquisition in 36 spectral channels [14]. The use of the Google Earth Engine platform and MODIS imagery can help understand the spatial patterns of land surface temperature in various locations, including the natural boundary area of the Krueng Aceh watershed for specific years, such as 2013, 2018 and 2023.

2. Research Method

Geospatial research on land surface temperature in the natural boundary region of the Krueng Aceh watershed utilizes Moderate Resolution Imaging Spectroradiometer (MODIS) imagery, specifically Terra Land Surface Temperature and Emissivity Daily Global 1km data. Based on Terra MODIS documentation, this image provides daily land

surface temperature data and emissivity values collected through high-resolution satellite sensing.

Data processing of Terra MODIS imagery is done by utilizing the Google Earth Engine (GEE) platform, which enables cloud-based geospatial data analysis. Land surface temperature data from Terra MODIS imagery is processed using the JavaScript programming language. The results of the processing were then analyzed to map the distribution of land surface temperature in the Krueng Aceh watershed area in the years 2013, 2018, and 2023. The methodology of this study can be seen in Figure 1.

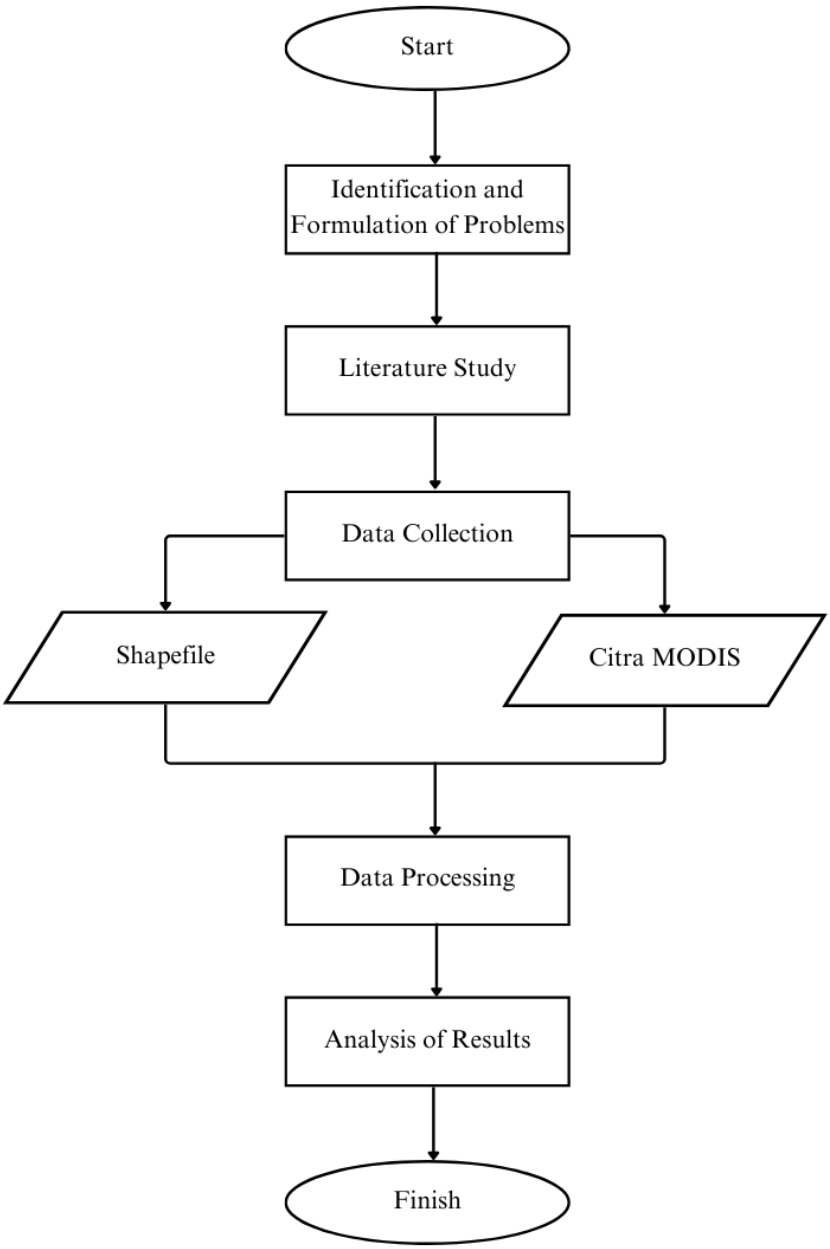

Figure 1. The methodology of the study

The first step of the study is identification and formulation of the problem .This stage aims to find and understand the concepts and problems to be solved. The analysis and problem formulation in this research are closely related to relevant geographic data and information. After the problem is identified, the next step is to determine the research objectives to be achieved and identify strategies and steps that can be taken to achieve these objectives. In this way, the entire research process can run systematically and purposefully, so as to effectively solve the problem. After that, a literature study was carried out by searching and collecting references in the form of relevant theories to support research. At this step of the literature study, various official sources such as scientific articles, books, academic journals, and previous studies will be reviewed to strengthen understanding of the problem being studied. Another aim of conducting a literature study is to present the relevant theories underlying the research. By conducting literature studies, researcher can find a broader perspective on the topic being studied and ensure that the research carried out has a significant contribution to the field of science concerned.

The next step is to collect the data needed for the research. In the study of land surface temperature in the Krueng Aceh watershed area, the data needed includes the Krueng Aceh watershed shape file as the study area and regional boundaries, as well as MODIS Terra Land Surface Temperature and Emissivity Daily Global 1 km satellite image data according to the date, month, and year needed. The Krueng Aceh watershed shape file data will be used to accurately identify the boundaries of the study area, while the MODIS satellite image data will be used to obtain land surface temperature information. This MODIS satellite image will be cropped according to the Krueng Aceh watershed area. After the data needed for the research is collected, the next step is to process the data on the Google Earth Engine platform. This data processing is carried out using the JavaScript programming language. The steps for processing data are as follows:

a. The first step of data processing on Terra MODIS image is to convert the temperature results obtained. Temperature values in MODIS images are initially expressed in Kelvin, then converted to Celsius to produce temperature values on a more understandable scale. The temperature conversion from Kelvin to Celsius is based on equation 3.1 below:

$$T℃ = TK \times 0.02 - 275.15 \quad (1)$$

In the MODIS image, to convert from Kelvin to Celsius temperature results, there is a constant that must be multiplied by the Kelvin temperature, which is 0.02. The purpose of multiplying by a constant is to facilitate interpretation and analysis.

b. Before displaying the land surface temperature map, first set the temperature parameters in the temperature range of 15°C to 40°C. Then, determine the color palette, namely blue, green, yellow, orange, and red. Setting this color palette serves to represent the temperature range, with blue indicating the lowest temperature and red indicating the highest temperature. Next, the land surface temperature image will be displayed on the Google Earth Engine map according to the settings that have been set.

c. The next step is to calculate the average land surface temperature that has been converted to Celsius for the Krueng Aceh watershed area. The results of the average land surface temperature will be displayed in the console feature, making it

possible to see the average value of surface temperature in the Krueng Aceh watershed area for each year analyzed.

d. The last step of the data processing process is calculating the area for each temperature range. The process of calculating the area according to the temperature range involves several steps, namely determining the temperature range by providing the minimum value, maximum value, and label. The temperature range used is in accordance with statistical calculations for class interval creation. The steps to compile class intervals are as follows:

   1) Determine the Range

$$Range = Nilai\ Maksimum - Nilai\ Minimum \quad (2)$$

   2) Define multiple Classes

$$Class\ Size = 1 + 3.322\ log\ (n) \quad (3)$$

   Description:
   n = Amount of Data

   3) Define the Length of the Class

$$Length\ of\ Class = \frac{Range}{Class\ Size} \quad (4)$$

   4) Determine Class Boundaries
   Determine the lower limit and upper limit for each class starting from the smallest value and adding to the class width in order.

e. After getting the temperature classes with a certain range, then calculate the area according to the temperature range. Finally, display the area result in the console by printing the labels of the temperature range, year, and area in km^2.

In the results analysis step, an in-depth analysis will be carried out on the average land surface temperature resulting from data processing on MODIS images and identifying trends in temperature changes over time. In addition, the spatial pattern of land surface temperature distribution is analyzed based on a predetermined temperature range. The analysis of the spatial pattern of land surface temperature distribution serves to understand the geographical distribution of land surface temperature distribution in the Krueng Aceh watershed area.

3. Result and Discussion

The land surface temperature classification process in the study was carried out through remote sensing interpretation techniques using MODIS Terra Land Surface Temperature and Emissivity Global 1 KM images using the Google Earth Engine platform. Land surface temperature measurements are based on the natural boundary area that extends from Banda Aceh City and Aceh Besar Regency, namely the Krueng Aceh Watershed in 2013, 2018 and 2023.

Based on the distribution of land surface temperature resulting from Terra MODIS images data processing for 2013, 2018, and 2023, the lowest temperature is 19°C and the highest temperature is 38°C. Next, the temperature values are calculated using class interval statistics which function to group land surface temperature areas in the Krueng Aceh watershed based on certain classes. Based on the calculation results, the land surface temperature classes are grouped as follows:

- Class 1: 19°C - 22°C
- Class 2: 23°C - 26°C
- Class 3: 27°C - 30°C
- Class 4: 31°C - 34°C
- Class 5: 35°C - 38°C

Land Surface Temperature in the Krueng Aceh Watershed in 2013

Based on data processing on satellite imagery in 2013, the average land surface temperature in the Krueng Aceh watershed is 29.11°C with grouping into 5 intervals according to the statistical class interval calculation. The results of grouping the average land surface temperature in Banda Aceh City in 2013 are presented in Table 1.

TABLE 1 LAND SURFACE TEMPERATURE CLASSIFICATION IN 2013

Class	Land Surface Temperature	Area	
		km^2	%
1	19°C - 22°C	109,25	5,52
2	23°C - 26°C	452,25	22,86
3	27°C - 30°C	707,56	35,76
4	31°C - 34°C	669,29	33,83
5	35°C - 38°C	38	1,92

Based on Table 1, the most dominant temperature class is class 3 (27°C - 30°C) which covers 35.76% of the total area of Krueng Aceh watershed. Then, followed by class 4 (31°C - 34°C) with a contribution of 33.83%, class 2 (23°C - 26°C) recorded 22.86%, class 1 (19°C - 22°C) at 5.52%, and class 5 (35°C - 38°C) only at 1.92% of the total study area. And the remaining 0.11% are images affected by cloud cover. Below is a visualization of the land surface temperature classification in the Krueng Aceh watershed in 2013 in Figure 2.

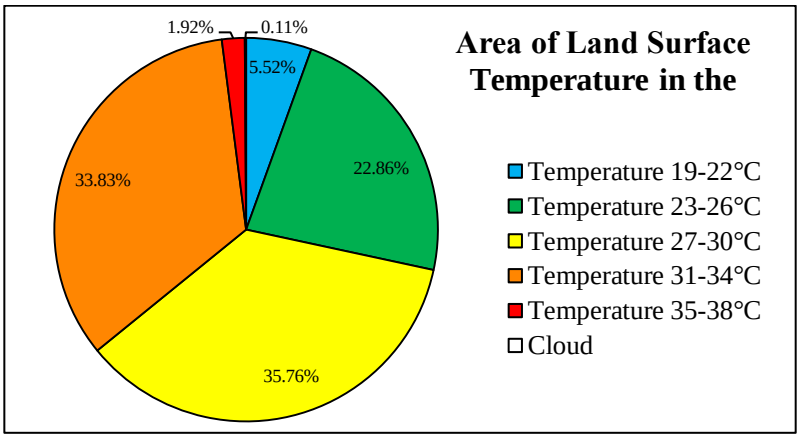

Figure 2. Bar Chart of Land Surface Temperature Area in the Krueng Aceh Watershed in 2013

Areas that have cloud cover and undetectable land surface temperature on the image are dominated by the downstream area of the Krueng Aceh watershed which is directly borders the Malacca Strait. The Terra MODIS image used is an image that predicts land surface temperature, namely MODIS Terra Land Surface Temperature and Emissivity Global 1 KM, and it is possible that the sensor of the image detects the downstream area of the Krueng Aceh watershed no longer as a land area but as a sea area. Although MODIS imagery can be used for sea surface temperature, it cannot measure sea surface temperature directly, as it is affected by factors in sea surface temperature.

The temperature of class 1 (19℃ - 22℃) and class 2 (23℃ - 26℃) are dominantly located on the outskirts of the Krueng Aceh watershed area in Aceh Besar district and a little in Pidie district. Several sub-districts in Aceh Besar that have both temperature classes are Leupung, Suka Makmur, Indrapuri, Cot Glie City, and Jantho City. Apart from that, temperature class 2 was also detected in the sub-district of Peukan Bada, Lhok Nga, Darul Kamal, Simpang Tiga, Kuta Malacca, Indra Puri, Seulawah Valley and Seulimeum. However, not all parts of these sub-districts were detected to have land surface temperatures for class 1 and class 2, generally only hilly areas with dense vegetation land types have these temperature classes.

The temperature of class 3 (27℃ - 30℃) and class 4 (31℃ - 34℃) - the two dominant temperature classes in the Krueng Aceh watershed - are distributed almost throughout the study area. The area of these two temperature classes is dominant in the center of the Krueng Aceh watershed which is located in Aceh Besar district and a little in the outskirts of Banda Aceh city. Meanwhile class 3 is generally detected for land use in the form of open land with sparse vegetation, while class 4 is detected in land use in the form of open land as well as ponds and mangrove forests. The sub-districts in Aceh Besar that have temperature classes 3 and 4 are Peukan Bada, Lhok Nga, Darul Imarah, Darul Kamal, Leupung, Simpang Tiga, Suka Makmur, Kuta Malaka, Indrapuri, Cot Glie City, Jantho City, Seulawah Valley, Seulimeum, and Darussalam. Meanwhile in Banda Aceh City, the sub-districts detected to have both temperature classes are Meuraxa, and Kuta Alam. In addition, the temperature of class 4 was also detected in the sub-districts of Darul Imarah, Ingin Jaya, Montasik, Blang Bintang, Kota Baro, Krueng Barona Jaya, Baitussalam, Syiah Kuala, Kuta Alam, Baiturrahman, and Jaya Baru.

Temperature class 5 (35℃ - 38℃) is an urban heat island area which is dominantly located in Banda Aceh City as an urban area. The land use in this temperature class is built-up land in the form of dense settlements, industries, and roads so that not only in Banda Aceh City, but Aceh Besar District which has a densely populated area also has this temperature class. Sub-districts in Aceh Besar District that have temperature class 5, especially sub-districts that are directly adjacent to Banda Aceh City, such as, Darussalam District, Krueng Barona Jaya District, Darul Imarah District, and slightly detected in Ingin Jaya District and Kota Baro District. For more details, it is shown in Figure 3.

Krueng Aceh River Watershed 2013

MODIS Image Processing Results

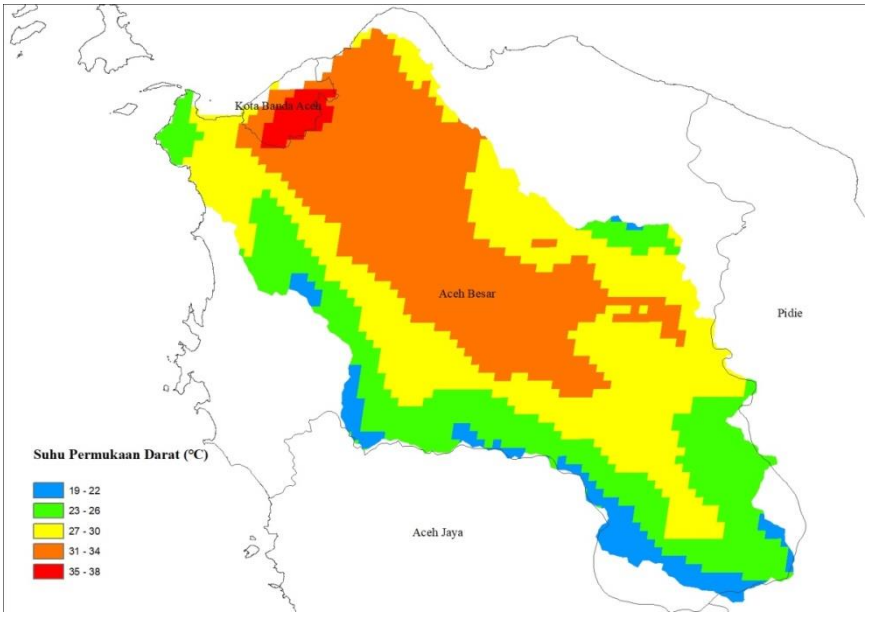

Figure 3. Terra MODIS Image Before and After Processing

Land Surface Temperature in the Krueng Aceh Watershed in 2018

Terra MODIS Land Surface Temperature satellite image data in 2018 has been processed using Google Earth Engine and obtained the average land surface temperature in the Krueng Aceh watershed, which is 29.5°C. Based on the calculation of the class interval, the land surface temperature was grouped into 5 classes. The grouping results are presented in Table 2.

TABLE 2 LAND SURFACE TEMPERATURE CLASSIFICATION IN 2018

Class	Land Surface Temperature	Area	
		km^2	%
1	19°C - 22°C	133,45	6,74
2	23°C - 26°C	400,67	20,25
3	27°C - 30°C	603,53	30,50
4	31°C - 34°C	754,83	38,15
5	35°C - 38°C	83,85	4,24

Based on Table 2. it can be seen that class 4 (31°C - 34°C) dominates the land surface temperature in the Krueng Aceh watershed with an area reaching 38.15% of the total area and has increased significantly from 2013. Followed by class 3 (27°C - 30°C) which decreased from 2013 to 30.50%. Next, class 2 (23°C - 26°C) with an area of 20.25% and this class also experienced a significant decrease from 2013. Lastly, class 5 and class 1 also increased compared to 2013 with class 5 reaching 4.24% while class 1 reached 6.74%. However, 0.11% of the Krueng Aceh watershed area is still affected by cloud cover, so the land surface temperature is not detected. A visualization of land surface temperature classification in the Krueng Aceh watershed in 2018 can be seen in Figure 4.

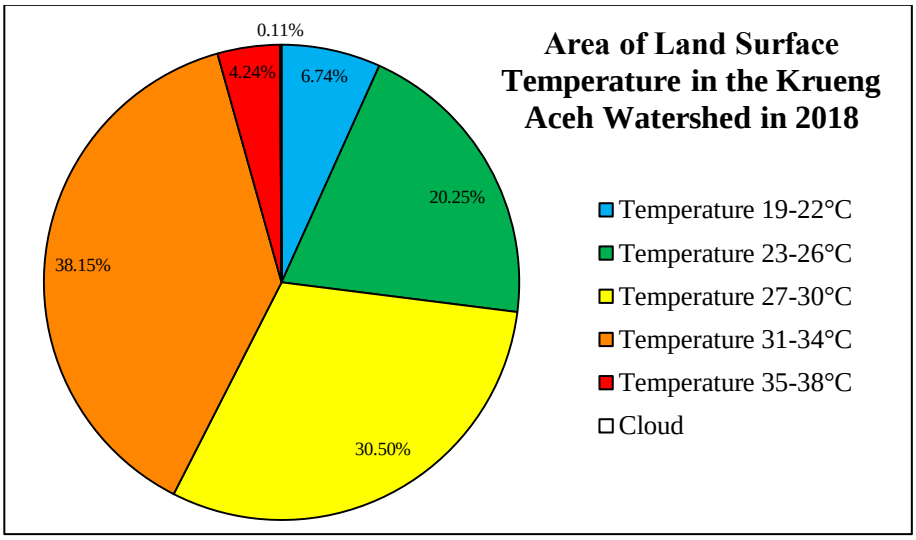

Figure 4. Bar Chart of Land Surface Temperature Area in the Krueng Aceh Watershed in 2018

Based on the results of Terra MODIS image data processing for 2018, areas that have cloud cover and undetectable land surface temperatures are still in the downstream area of the Krueng Aceh watershed which is directly borders the Malacca Strait. While for class 1 (19°C - 22°C), if in 2013 it only had an area of 10,924.71 ha, but in 2018 it increased to 13,345.10 ha and the location is still the same as in 2013, which is dominantly located in Aceh Besar District, such as in Leupung Sub-District, Indrapuri Sub-District, Suka Makmur Sub-District, Jantho City, and Cot Glie City. Apart from that, there are also a few in Pidie District. Generally, class 1 is detected for areas with land use types such as hills with dense vegetation.

Areas with temperature class 2 (23°C - 26°C) in 2013 and 2018 also did not change significantly, which are located around the boundary of the Krueng Aceh watershed in Aceh Besar District. There are 10 sub-districts in Aceh Besar District that have this

temperature class, such as Seulawah Valley District, Seulimuem Sub-District, Jantho City, Cot Glie City, Lhok Nga Sub-District, Leupung Sub-District, Simpang Tiga Sub-District, Suka Makmur Sub-District, Darul Kamal Sub-District, and Indrapuri Sub-District. Class 2 temperatures were also detected slightly in the Krueng Aceh watershed area in Pidie District. However, not all parts of these sub-districts have a class 2 land surface temperature, only areas covered by dense vegetation, while other parts are in other temperature classes.

Class 3 (27℃ - 30℃) and class 4 (31℃ - 34℃) are still the two most common temperature classes found in the Krueng Aceh watershed. These two classes are almost spread throughout the study area and are mostly found in the central part of the Krueng Aceh watershed in Aceh Besar district. However, class 4 is also found slightly in the Banda Aceh City area, especially for areas of Banda Aceh City that have little built-up land, such as in Meuraxa Sub-District, Kuta Alam Sub-District, Jaya Baru Sub-District, and Kuta Raja sub-District. Open land with minimal vegetation is the land use detected for class 3, while open land with little built-up land and also ponds is the land use type for class 4.

The last temperature class is class 5 (35℃ - 38℃) which is a very high temperature. In this Krueng Aceh watershed, the area that has this temperature class is dominated by Banda Aceh City. Some areas in Aceh Besar also have this temperature class. However, this is different from 2013, which was only detected in sub-districts directly bordering Banda Aceh City, such as Darussalam Sub-district, Krueng Barona Jaya Sub-district, Ingin Jaya Sub-district, Darul Imarah Sub-district, and a little in Kota Baro Sub-district, in 2018 other sub-districts such as Peukan Bada, Montasik, and Blang Bintang were also detected to have temperature class 5. This temperature class is generally detected for land use in the form of built-up land in the form of dense settlements, industry, and roads. This is very much in accordance with Banda Aceh City as an urban area. The following is shown in Figure 5 for more complete results.

Krueng Aceh River Watershed 2018

MODIS Image Processing Results

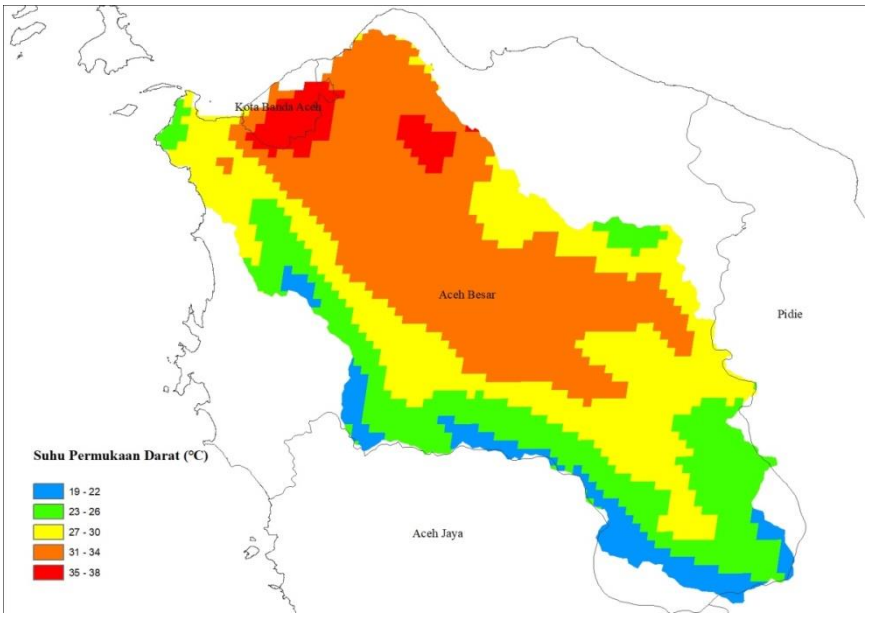

Figure 5. Terra MODIS Image Before and After Processing

Land Surface Temperature in the Krueng Aceh Watershed in 2023

The average land surface temperature in the Krueng Aceh watershed in 2023 is 29.19°C. This result was obtained by processing data on Terra MODIS Land Surface Temperature images by utilizing the Google Earth Engine cloud computing platform. After processing, the land surface temperature is then grouped into 5 classes according to the calculation of the statistical class intervals. Table 3. the following displays the results of the class division.

TABLE 3 LAND SURFACE TEMPERATURE CLASSIFICATION IN 2023

Class	Land Surface Temperature	Area	
		km^2	%
1	19°C - 22°C	152,20	7,69
2	23°C - 26°C	444,89	22,49
3	27°C - 30°C	633,87	32,04
4	31°C - 34°C	643,38	32,52
5	35°C - 38°C	102	5,16

Based on the table above, class 4 (31°C - 34°C) is still the dominating temperature class from the other classes despite a significant decrease from 2018 which reached an area of 38.15% to 32.52% in 2023. The second dominant temperature class is still temperature class 3 (27°C - 30°C) which in 2023 has again increased by reaching an area of 32.04% of the total, and only slightly different in area from class 4. Then, class 1 (19°C - 22°C), class 2 (23°C - 26°C), and class 5 (>35°C) have also increased compared to 2018, with the respective areas of the three classes in 2023 being 7.69%, 22.49% and 5.16% of the total study area. And just like in 2013 and 2018, in 2023 there are also images that have cloud cover so that they cannot detect land surface temperatures covering 0.11%. Figure 6 below is a visualization of the land surface temperature classification in the Krueng Aceh watershed in 2023.

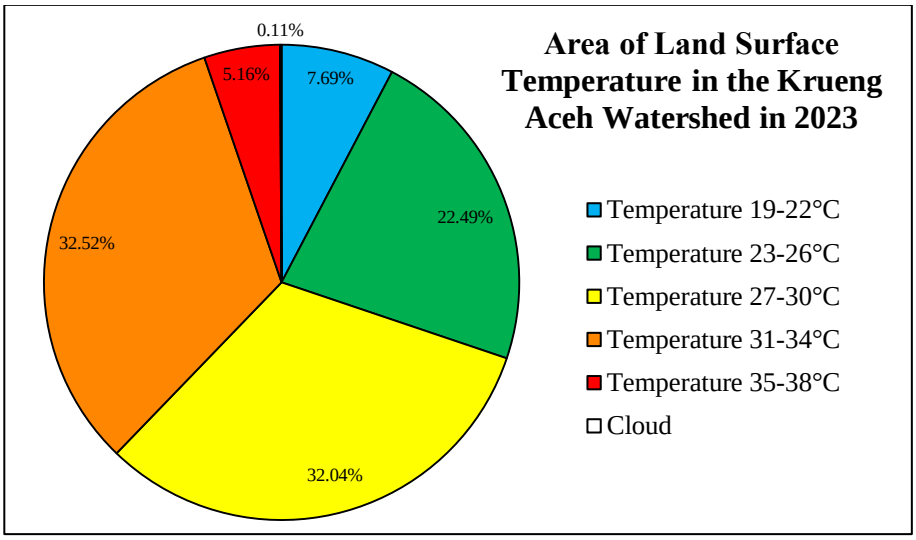

Figure 6. Bar Chart of Land Surface Temperature Area in the Krueng Aceh Watershed in 2023

The results of Terra MODIS image data processing for 2023, in the downstream area of the Krueng Aceh watershed have cloud cover on the image, so it cannot detect land surface temperature for the region. This also happened in 2018 and 2023. As for class 1 (19°C - 22°C), the areas that have this class are still in Leupung Sub-District, Indrapuri Sub-District, Suka Makmur Sub-District, Jantho City, Cot Glie City, and a few in Pidie Regency. The areas detected to have class 1 are generally hilly land use type areas with dense vegetation. In 2023, this has again increased in size from 2018.

The Krueng Aceh watershed area with temperature class 2 (23°C - 26°C) in 2023 is still located the same as in 2013 and 2018. The Krueng Aceh watershed area that has this class is around the outskirts of the Krueng Aceh watershed in Aceh Besar district. The Aceh Besar areas that have temperature class 2 are generally areas with dense vegetation such as those in Seulawah Valley Sub-District, Seulimuem Sub-District,

Jantho City, Cot Glie City, Lhok Nga Sub-District, Leupung Sub-District, Simpang Tiga Sub-District, Suka Makmur Sub-District, Darul Kamal Sub-District, Kuta Malaka Sub-District and Indrapuri Sub-District. In addition, the Krueng Aceh watershed area in Pidie District also has this temperature class.

Next, for class 3 (26℃ - 30℃) and class 4 (31℃ - 34℃) are the two dominant temperature classes in the Krueng Aceh watershed so that they spread almost throughout the study area. Except for changes in area, the location of these two classes in 2023 is not much different if based on the results of data processing in 2013 and 2018, which is still dominantly located in the central part of the Krueng Aceh watershed, more precisely in Aceh Besar District and class 4 which is also found in Banda Aceh City for the type of area that has little built-up land, such as in Meuraxa Sub-District, Kuta Alam Sub-District, Jaya Baru Sub-District, and Kuta Raja Sub-District. Generally, areas included in class 3 are areas that have open land, but there is still vegetation, although not much. As for class 4, areas included in this class are types of areas where there is a lot of open land but only minimal or sparse built-up land, and are also detected in pond areas and mangrove forests.

Temperature class 5 areas (>35℃) for the Krueng Aceh watershed are still commonly detected in Banda Aceh City and its surroundings, namely sub-districts in Aceh Besar that are directly adjacent to Banda Aceh City, such as Baitussalam Sub-District, Darussalam Sub-District, Krueng Barona Jaya Sub-District, Ingin Jaya Sub-District, and Darul Imarah Sub-District. This temperature class has increased when compared to 2018, and sub-districts in Aceh Besar that also have other class 5 land surface temperatures, namely Montasik, Kota Baro, and Blang Bintang. The increase in temperature area for this very high temperature class can be triggered by the increasing number of land changes to built-up land in several locations, because land use for the temperature class is in the form of built-up land, such as densely populated residential areas, paved roads, and industrial buildings. Figure 7 below is the result for more details.

Krueng Aceh River Watershed 2023

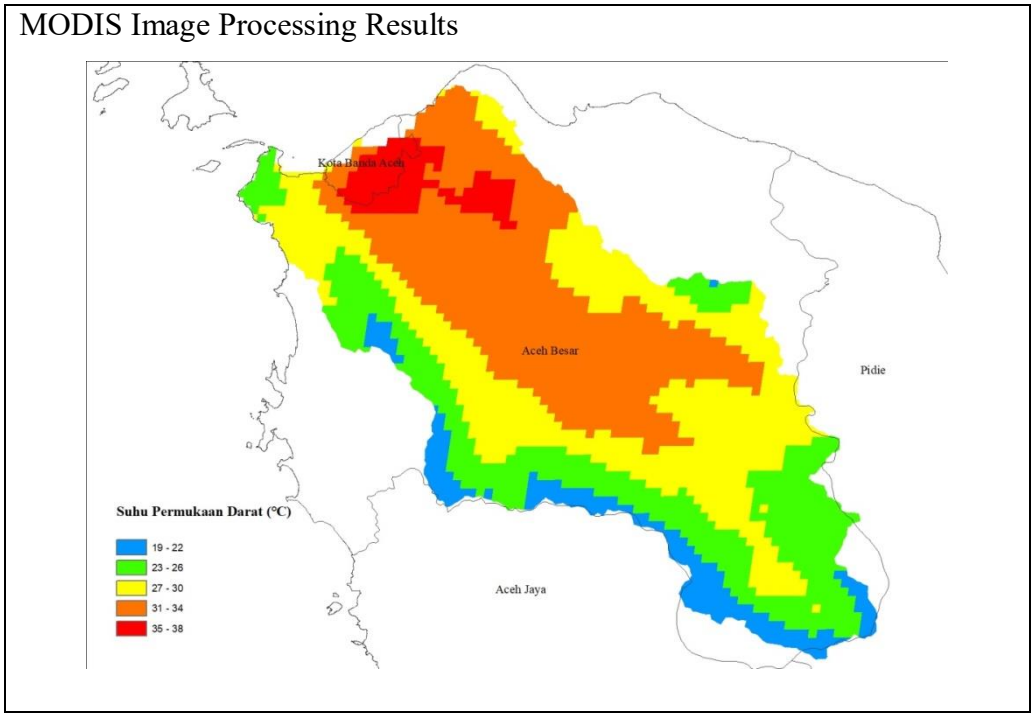

Figure 7. Terra MODIS Image Before and After Processing

4. Conclusion

Land surface temperature in the natural boundary area of Krueng Aceh Watershed shows similar changes and spatial patterns in 2013, 2018, and 2023. In 2013, the average temperature was recorded at 29.11℃ and increased to 29.5℃ in 2018, with an expansion of the area included in temperature class 4 (31℃ - 34℃) and class 5 (35℃ - 38℃). However, in 2023 the average temperature slightly decreased to 29.19℃ as the area of temperature class 4 decreased and the area of temperature classes 1 and 2 increased. Spatially, low temperatures (class 1 and class 2) were detected on the edge of the Krueng Aceh watershed with hilly land and dense vegetation, while moderate temperatures (class 3 and class 4) dominated the central part of the watershed with sparse vegetation and open land. Very high temperatures (class 5) were found in urbanized areas that have a lot of built-up land.

References

[1] A. K. Taloor, D. S. Manhas, & G. C. Kothyari, "Retrieval of Land Surface Temperature, Normalized Difference Moisture Index, Normalized Difference Water Index of The Ravi Basin Using Landsat Data," *Applied Computing and Geosciences*, vol. 9, March. 2021.

[2] P. C. Latue, H. Rakuasa, G. Somae, & A. Muin, "Analisis Perubahan Suhu Permukaan Daratan di Kabupaten Seram Bagian Barat Menggunakan Platform Berbasis Cloud Google Earth Engine," *Sudo Jurnal Teknik Informatika,* vol. 2, no. 2, pp. 45-51, May. 2023.

[3] H. Rakuasa, & M. A. Lasaiba, "Analisis Suhu Permukaan Daratan di Kabupaten Buru Menggunakan Data Citra Satelit MODIS Berbasis Cloud Computing Google

Earth Engine," *GEOFORUM Jurnal Geografi dan Pendidikan Feografi*, vol. 2, no. 2, pp. 71-80, December. 2023.

[4] H. Rakuasa, & S. Pertuack, "Pola Perubahan Suhu Permukaan Daratan di Kecamatan Ternate Tengah, Kota Ternate Tahun 2013 dan 2023 Menggunakan Google Earth Engine," *Sudo Jurnal Teknik Informatika*, vol. 2, no. 2, pp. 78-85, June. 2023.

[5] D. Darwin, S. Syahrul, & H. Basri, "Analisis Karakteristik Hidrologi DAS Krueng Aceh, Provinsi Aceh (Studi Kasus Sub DAS Krueng Jreu dan Sub DAS Krueng Khea)," *Rona Teknik Pertanian*, vol. 14, no. 1, pp. 58-72, April. 2021.

[6] T. Ferijal, M. Mustafril, & D. S. Jayanti, "Dampak Perubahan Iklim Terhadap Debit Andalan Sungai Krueng Aceh," *Rona Teknik Pertanian*, vol. 9, no. 1, pp. 50-61, April. 2016.

[7] N. E. Safitri, T. Ferijal, & S. Syahrul, "Perubahan Iklim Di DAS Krueng Aceh," *Jurnal Ilmiah Mahasiswa Pertanian*, vol. 8, no. 1, pp. 296-300, February. 2023.

[8] R. Rahmayanti. "Dampak Perubahan Lahan pada DAS Krueng Aceh terhadap Neraca Air Menggunakan Metode Thornthwaite Mather," B.T Thesis, Department of Enviromental Engineering, Faculty of Science and Engineering, Universitas Islam Negeri Ar-Raniry, Indonesia, 2023.

[9] L. M. Prayogo, "Platform google earth engine untuk pemetaan suhu permukaan daratan dari data series modis," *DoubleClick: Journal of Computer and Information Technology*, vol. 5, no. 1, pp. 25-31, Agustus. 2021.

[10] F. S. Hehanussa, D. R. S. Sumunar, & H. Rakuasa, "Pemanfaatan Google Earth Engine Untuk Identifikasi Perubahan Suhu Permukaan Daratan Kabupaten Buru Selatan Berbasis Cloud Computing," *Gudang Jurnal Multidisiplin Ilmu*, vol. 1, no. 1, pp. 37-45, July. 2023.

[11] S. S. Rijal, *Mengolah Citra Pengindraan Jauh Dengan Google Earth Engine*, Deepublish, Yogyakarta, p.7, 2020.

[12] O. Mutanga, & L. Kumar, "Google Earth Engine Applications," *Remote sensing*, vol. 11, no. 5, pp. 591, March. 2019.

[13] K. A. D. Sukowati, "Pemanfaatan Data Modis untuk Mengukur Suhu Permukaan Bumi dalam Rangka Pemantauan Pemanasan Global," B.T Thesis, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Indonesia, 2009.

[14] Mujiono, *Buku Ajar Pengindraan Jauh untuk Pertanian*, Elmarkazi, Bengkulu, p.7, 2019.