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Analysis of Land Surface Temperature Changes in East Lombok Regency Using the Cloud-Based Platform Google Earth Engine

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Abstract. This study uses Google Earth Engine, a cloud computing platform, to examine variations in land surface temperature in East Lombok Regency between 2010 and 2020. This study uses MODIS satellite data and is analyzed using Google Earth Engine by adapting a mathematical method—namely, the Random Forest Algorithm from discrete mathematics. According to the results, the temperature increased from its lowest point in 2010 (14.32°C) to its maximum point in 2020 (36.19°C), rising to 16.67°C and 37.74°C. Due to residential growth, Wanasaba, Pringgabaya, and Sambelia saw the biggest increases. Comprehensive temperature monitoring is made possible by Google Earth Engine, which facilitates the effective processing of large-scale spatial data. These results offer a scientific foundation for policy decisions and are essential for environmental management and climate change mitigation. In addition to supporting environmental monitoring initiatives, this study provides a reference for related studies in other areas dealing with issues related to land use and climate change. This research is important for the Central Lombok government as a basis for mitigation efforts in responding to temperature changes and their implications for land use change.

Keywords: *cloud computing; data processing;climate changes; JavaScript.*

1 Introduction

Land Surface Temperature (LST) plays a vital role in studies related to weather, climate, and the environment [1]. Several elements affect LST, including atmospheric temperature, sunlight intensity, moisture levels, soil composition, surface characteristics, and geographic position [2]. Variations in LST have considerable effects on both ecosystems and human livelihoods. Human-induced factors like deforestation and greenhouse gas emissions contribute to rising surface temperatures and climate change, which in turn can disturb ecological stability and threaten public health [3].

According to Zulkarnain, land use changes, including deforestation, forest-to-plantation conversion, agricultural expansion, and urbanization, contribute to rising surface temperatures [4]. The removal of forests eliminates natural elements like trees and moist

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soil that help absorb heat, whereas urban development introduces materials such as asphalt and concrete that tend to retain heat [5]. Elevated surface temperatures are commonly observed in areas with dense buildings, large impervious surfaces, and regions where heat dissipation through advection and radiation is limited, such as urban centers with tall structures [6].

Changes in land surface temperature are essential indicators for understanding the dynamics of climate change and its impacts on ecosystems and human activities. In Indonesia, particularly in East Lombok Regency, temperature-related issues have become increasingly concerning due to their wide-ranging effects, including declining agricultural productivity, ecosystem changes, and heightened disaster risks. Long-term monitoring of land surface temperature provides a clearer understanding of temperature change patterns, which is vital for informed policymaking and climate change mitigation planning.
Cloud-based platforms such as Google Earth Engine (GEE) have become indispensable tools due to advancements in remote sensing technologies. By giving users access to vast satellite datasets and potent cloud computing resources, GEE makes it easier to analyze data from remote sensing on a big scale. A free, open-source cloud-based system called Google Earth Engine (GEE) makes it possible to interpret satellite imagery and other geospatial data, making it a very powerful platform for geospatial analysis [4]. Monitoring temperature trends over time is made simpler by this platform's ability to analyze land surface temperature data effectively across temporal and spatial scales [13], [15].

This research utilizes imagery from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor to examine variations in surface temperature [14]. Through Google Earth Engine, MODIS data can be accessed directly and is commonly employed in various applications, including monitoring land surface temperature and vegetation, due to its adequate spatial resolution for in-depth analysis [9].

This study aims to examine variations in land surface temperature in East Lombok Regency by utilizing satellite data accessible via Google Earth Engine. This approach aims to provide insights into the patterns and trends of temperature changes in the region, supporting climate change mitigation efforts in East Lombok and its surroundings.

2 Research Method

The study was conducted in the West Nusa Tenggara Province's East Lombok Regency. Google Earth Engine (https://earthengine.google.com/) was used to retrieve and process the MODIS Terra Land Surface Temperature and Emissivity 8-Day Global dataset. In particular, Figure 1 displays the MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1km product, which is a NASA satellite dataset. With a geographical resolution of one kilometer, this dataset provides global measurements of land surface temperature and emissivity. The MODIS sensor aboard the Terra satellite gathers the data. Applications for the MOD11A2.061 product are numerous and include weather modeling, water resource assessment, wildfire monitoring, and surface temperature assessment [10]. On the following is the step of the research.

This study applies a quantitative approach based on spatial analysis to analyze the dynamics of land cover change in East Lombok regency. Google Earth Engine (GEE) was used as the primary platform for processing and analyzing satellite imagery data. The methodological steps implemented are as follows:

1. Data and Data Sources

This study used Landsat 8 satellite imagery data for land cover analysis:

- Observation Years: between 2010 and 2020.
- Data Source: Imagery accessed through the Google Earth Engine repository.

2. Data Preprocessing

Preprocessing was performed to improve data quality:

- Cloud and Shadow Masking: Using GEE's built-in function to remove clouds and shadows.
- Area of Interest (AOI): Cropping the imagery within East Lombok Regency based on temperature changes.

The following formula is used to determine temperature:

$$T = f(x) = \frac{K2}{ln\left(\frac{K_1}{L\lambda} + 1\right)}$$

Explanation:

T : Radiant temperature
$L\lambda$ S : Spectral radiance
$K2$: 1282.71
$K1$: 666,09 $(w/m^2 * ster * \mu m)$

Then the radiant temperature is converted to surface temperature using the following equation:

$$Ts = \left(\frac{TB}{1 + \left(\frac{\lambda TB}{\rho}\right) ln\epsilon}\right),$$

$$\rho = \frac{hc}{K(1.438 * 10^2 mK)}$$

Explanation:

Ts : Surface temperature
ϵ : Emissivity
TB : Radiant temperature

Λ : Emitted wavelength (11,5 μm)

3. Land Cover Classification

The directional classification method used to identify and group land cover types is as follows:

- Land Cover Classes: Open Land, Rice Fields, Residential Areas, Highways, and Vegetation.
- Training Data: Sample data was taken based on visual interpretation of the imagery for each class.
- Classification Algorithm: Using the Random Forest algorithm, which has high accuracy for spatial data.

Mathematically, the Random Forest method is an ensemble learning algorithm that constructs a set of decision trees $\{T_1, T_2, \dots, T_B\}$, where B is the number of trees, and combines their outputs to improve classification accuracy and reduce overfitting. Each tree is built using a bootstrap sample from the training data, and at each node, a random subset of features is selected to determine the best split.

Given a feature vector $\boldsymbol{x}$ **t**he predicted class $\hat{y}$ is determined by majority voting:

$$\hat{y} = mode\{T_1(\boldsymbol{x}), T_2(\boldsymbol{x}), \dots, T_B(\boldsymbol{x})\}$$

In the context of this study in Central Lombok, the Random Forest algorithm is implemented within Google Earth Engine to classify land cover types using MODIS satellite data. The input features include vegetation indices (e.g., NDVI), surface temperature, and other spectral bands. By leveraging the randomness in both data and feature selection, the model achieves high robustness and generalization in detecting land use changes influenced by climate variability.

4. Land Cover Change Analysis

Land cover change analysis was conducted using:

- Overlay Analysis: Comparing classification results.
- Trend Change: Quantitative changes every 30 meters were analyzed for each class.

5. Validation of Classification Results

Validation is performed to ensure classification accuracy that needs a confusion matrix. Confusion Matrix is an analytical tool used to analyze the performance of a classification model in machine learning. This matrix provides a detailed overview of how the model's predictions compare to the actual data.

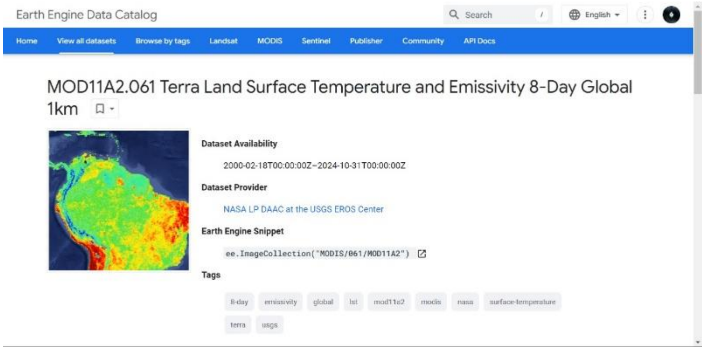

Figure 1 MODIS image dataset display on Google Earth Engine

To investigate land surface temperatures in East Lombok Regency between the years 2010 and 2020, JavaScript was used for all data processing and analysis within the Google Earth Engine platform. The following steps are part of the data processing and analysis procedures:

1. Import MODIS Image Collection to load MODIS imagery from the GEE catalog
```
var modisLST = ee.ImageCollection('MODIS/006/MOD11A2')
```
2. Set time variables to specify the research time period.
```
.filterDate('2010-01-01', '2010-12-31');
```
3. To extract the average pixel values of LST Day 1 km (MOD11A2), which are the mean of all MOD11A1 pixel values over an 8-day period, select the LST Day 1 km band.
```
.select('LST_Day_1km')
```
4. Clip Data by Region and Show on Map: This method uses the East Lombok Regency border shapefile to process data based on the research location and show it on the map.
```
clip(lombokTimur);
```
5. This syntax is used to convert LST values from Kelvin to Celsius: Convert Kelvin to Celcius.
```
var convertToCelsius = function(image) {
  return image.multiply(0.02).subtract(273.15)
    .copyProperties(image, ['system:time_start']);
};
```
6. Visualize Surface or Emission Temperature on Map.
```
var lstVisParams = {min: 15, max: 40, palette: ['blue',
'green', 'yellow', 'orange', 'red']};
```

7. Update the GEE Layer with the Surface Temperature Analysis Results.

```
Map.addLayer(lst2010, lstVisParams, 'LST 2010');
```

8. Export LST Analysis Results to Google Drive to save the results, which can be further analyzed in GIS software.

```
Export.image.toDrive({
  image: lst2010,
  description: 'LST_Lombok_Timur_2010',
  scale: 1000,
  region: lombokTimur,
  fileFormat: 'GeoTIFF'
});
```

ArcGIS software is used for the categorization process after the land surface temperature analysis results have been downloaded from Google Drive [7], [8], and [11]. Table 1 displays the land surface temperature classification.

Table 1. Land Surface Temperature Classification

No	Class	Description
1	Very Low	$< 20° C$
2	Low	$20° C - 25° C$
3	Medium	$25{,}1° C - 30° C$
4	High	$30{,}1° C - 35° C$
5	Very High	$> 35° C$

The analysis and classification in this study refer to research outlined in Table 1.

3 Results and Discussions

Using satellite sensors and the Split Window Algorithm (SWA), the MODIS satellite measures temperature. One of the most important factors in the thermal band is brightness temperature.

According to the analysis conducted in East Lombok Regency using the MODIS Terra Land Surface Temperature and Emissivity 8-Day Global dataset, land surface temperature (LST) values vary depending on a number of variables, such as geographic location, temporal variations, climatic conditions, and land use patterns. Figure 2 shows the LST values in East Lombok Regency. 2010 saw the greatest LST value of 36.19°C and the lowest of 14.32°C. By 2020, the highest temperature reached 37.74°C, while the lowest temperature was 16.67°C. The colors blue and red indicate the lowest and highest temperatures, respectively. Figures 2 and 3 on the following show the land surface temperature classification maps for East Lombok Regency.

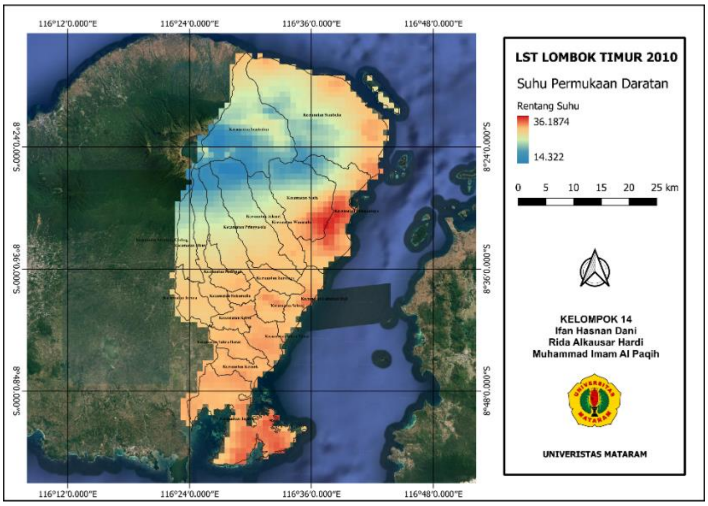

Figure 2 Average land surface temperature in 2010

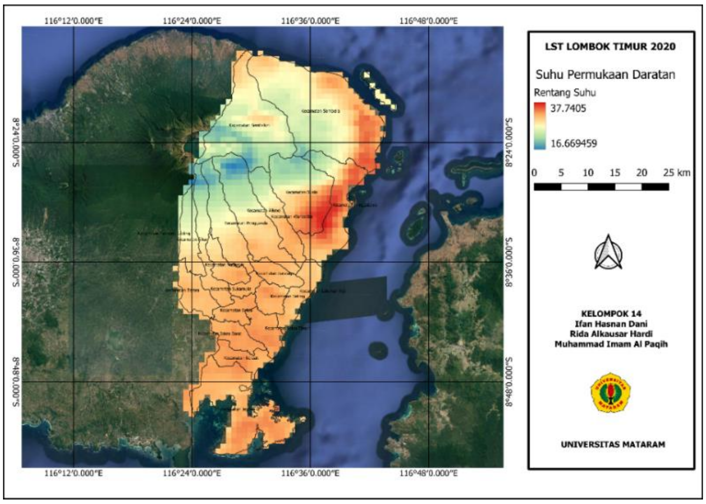

Figure 3 Average land surface temperature in 2020

Five groups of land surface temperature classes were used in this investigation. According to the analysis's findings, 589.58 hectares, or 0.38%, of the land surface had a very high temperature in 2010. 63,516.18 hectares, or 40.51%, were covered by the high-temperature class; 49,049.72 hectares, or 31.29%, by the medium-temperature class; 32,561.90 hectares, or 20.77%; and 11,055.18 hectares, or 7.05%, by the very low-temperature class. Additionally, the investigation showed that East Lombok Regency's coastline regions had the highest land surface temperatures.

In 2020, the area with very high land surface temperature increased to 4,618.61 hectares, or 2.95%. The high-temperature class covered 79,587.27 hectares, or 50.77%; the medium-temperature class covered 39,638.48 hectares, or 25.28%; the low-temperature class covered 29,724.52 hectares, or 18.96%; and the very low-temperature class covered 3,213.68 hectares, or 2.05%. The analysis also showed that spatially, very high land surface temperatures remained in the coastal areas of East Lombok Regency. The comparison can be seen in the Table 2.

Table 2. Comparison of Land Surface Temperature in 2010 and 2020

Class	2010 (Area/ha)	2020 (Area/ha)	2010 (%)	2020 (%)	Difference (Area/ha)	Differenc e (%)
Very High	589.58	4.618,61	0,38%	2,95%	+4.029,03	+2,57
High	63.516,18	79.587,27	40,51%	50,77%	+16.071,09	+10,26
Medium	49.049,72	39.638,48	31,29%	25,28%	-9.411,24	-6,01
Low	32.561,90	29.724,52	20,77%	18,96%	-2.837,38	-1,81
Very Low	11.055,18	3.203,68	7,05%	2,0%	-7.851,50	-4,97

The increase in built-up areas in a region can significantly affect the rise in land surface temperature, as observed in East Lombok Regency, particularly in Suela, Pringgabaya, and Sambelia districts. When land previously used for agriculture or green open spaces is converted into densely populated areas, human activities increase, including the construction of buildings, roads, and other infrastructure. Building structures have a greater capacity to absorb and retain heat compared to open land. Consequently, air temperatures in urban areas tend to be higher than in forested regions. Surface albedo factors also contribute, where darker surfaces absorb more heat than lighter ones.

There are various advantages to using Google Earth Engine, a cloud-based computer platform, to examine variations in East Lombok Regency's land surface temperature, including:

1) Through analysis using Google Earth Engine, changes in land surface temperature in East Lombok Regency can be monitored over time. This approach enables the observation of change patterns, trends, and temperature fluctuations within specific periods. Such information is valuable for understanding temperature variations, monitoring local climate changes, and identifying extreme temperature patterns.
2) Studies on the impacts of land surface temperature changes can provide insights into their effects on human health, the environment, and ecosystems in Central Ternate District. These data can be used to identify areas requiring greater attention in efforts to mitigate and adapt to temperature changes.
3) The analysis of surface temperature changes can contribute to the preservation of natural resources, including forests, agricultural land, and agricultural ecosystems. Effective planning and management can prevent environmental damage and protect habitats for flora and fauna.

4 Conclusion

The cloud-based Google Earth Engine technology offers substantial advantages for tracking and evaluating variations in the land surface temperature in East Lombok Regency. This study was successful in identifying trends in temperature change and comprehending how they are distributed. The results indicate that in 2010, the land surface temperature in East Lombok Regency ranged from 14.32°C to 36.19°C. By 2020, the lowest temperature increased to 16.67°C, while the highest temperature reached 37.74°C. As a result, the region's land surface temperature has significantly increased. The growth of residential areas in the districts of Wanasaba, Pringgabaya, and Sambelia is mostly responsible for this temperature increase. The results of this study offer a vital foundation for choices on the management of natural resources and the environment, including initiatives to slow down climate change. The use of cloud-computing technology offers advantages in terms of efficiency, speed, and the ability to analyze large-scale spatial data, enabling comprehensive monitoring. This research contributes to the advancement of science and technology in the field of environmental monitoring and can serve as an important reference for similar studies in other regions. Thus, this study plays a vital role in supporting environmental sustainability and enhancing understanding of climate change in East Lombok Regency.

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6 References

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Appendix

The JavaScripts of the research

```
// Definisikan area studi (Lombok Timur)
var lombokTimur =
ee.FeatureCollection('FAO/GAUL/2015/level2')
```

```
  .filter(ee.Filter.eq('ADM2_NAME', 'Lombok Timur'));
// Ambil data MODIS LST (MOD11A2) - 8 hari rata-rata
var modisLST =
ee.ImageCollection('MODIS/006/MOD11A2').select('LST_Day_1km
').filterBounds(lombokTimur).filterDate('2010-01-01',
'2010-12-31');
// Konversi suhu dari Kelvin ke Celsius
var convertToCelsius = function(image) {return
image.multiply(0.02).subtract(273.15).copyProperties(image,
['system:time_start']);
};
var modisLST_C = modisLST.map(convertToCelsius);
var lst2010 = modisLST_C.mean().clip(lombokTimur);
// Visualisasi suhu permukaan
var lstVisParams = {min: 15, max: 40, palette: ['blue',
'green', 'yellow', 'orange', 'red']};
Map.centerObject(lombokTimur, 9);
Map.addLayer(lst2010, lstVisParams, 'LST 2010');
// Membuat klasifikasi suhu
var suhuSangatRendah = lst2010.lt(20).selfMask();
var suhuRendah =
lst2010.gte(20).and(lst2010.lt(25)).selfMask();
var suhuSedang =
lst2010.gte(25).and(lst2010.lt(30)).selfMask();
var suhuTinggi =
lst2010.gte(30).and(lst2010.lt(35)).selfMask();
var suhuSangatTinggi = lst2010.gt(35).selfMask();
// Visualisasi kategori suhu di peta
Map.addLayer(suhuSangatRendah, {palette: ['blue']}, 'Suhu
Sangat Rendah (<20°C)');
Map.addLayer(suhuRendah, {palette: ['green']}, 'Suhu Rendah
(20-25°C)');
Map.addLayer(suhuSedang, {palette: ['yellow']}, 'Suhu
Sedang (25-30°C)');
Map.addLayer(suhuTinggi, {palette: ['orange']}, 'Suhu
Tinggi (30-35°C)');
Map.addLayer(suhuSangatTinggi, {palette: ['red']}, 'Suhu
Sangat Tinggi (>35°C)');
// Fungsi untuk menghitung luas wilayah (ha) untuk setiap
kategori
var pixelArea = ee.Image.pixelArea();
function hitungLuas(mask, name) {var luas =
pixelArea.updateMask(mask).reduceRegion({reducer:
```

```
ee.Reducer.sum(),geometry: lombokTimur,scale:
1000,maxPixels: 1e9}).get('area');
  // Konversi luas dari meter persegi ke hektar
  luas = ee.Number(luas).divide(10000);
  print('Luas ' + name + ' (ha):', luas);
  return luas;}
// Hitung luas masing-masing kategori suhu
var luasSangatRendah = hitungLuas(suhuSangatRendah, 'Suhu
Sangat Rendah (<20°C)');
var luasRendah = hitungLuas(suhuRendah, 'Suhu Rendah (20-
25°C)');
var luasSedang = hitungLuas(suhuSedang, 'Suhu Sedang (25-
30°C)');
var luasTinggi = hitungLuas(suhuTinggi, 'Suhu Tinggi (30-
35°C)');
var luasSangatTinggi = hitungLuas(suhuSangatTinggi, 'Suhu
Sangat Tinggi (>35°C)');
// Hitung total luas wilayah
var totalLuas =
luasSangatRendah.add(luasRendah).add(luasSedang).add(luasTi
nggi).add(luasSangatTinggi);
print('Total Luas Wilayah (ha):', totalLuas);
// Hitung persentase luas untuk setiap kategori
function hitungPersentase(luas, totalLuas, name) {
  var persentase = luas.divide(totalLuas).multiply(100);
  print('Persentase ' + name + ' (%):', persentase);
  return persentase;}
var persenSangatRendah = hitungPersentase(luasSangatRendah,
totalLuas, 'Suhu Sangat Rendah (<20°C)');
var persenRendah = hitungPersentase(luasRendah, totalLuas,
'Suhu Rendah (20-25°C)');
var persenSedang = hitungPersentase(luasSedang, totalLuas,
'Suhu Sedang (25-30°C)');
var persenTinggi = hitungPersentase(luasTinggi, totalLuas,
'Suhu Tinggi (30-35°C)');
var persenSangatTinggi = hitungPersentase(luasSangatTinggi,
totalLuas, 'Suhu Sangat Tinggi (>35°C)');
// Menghitung suhu tertinggi dan terendah
var suhuTertinggi = lst2010.reduceRegion({reducer:
ee.Reducer.max(),geometry: lombokTimur,scale:
1000,maxPixels: 1e9}).get('LST_Day_1km');
```

```
var suhuTerendah = lst2010.reduceRegion({reducer:
ee.Reducer.min(),geometry: lombokTimur,scale:
1000,maxPixels: 1e9}).get('LST_Day_1km');
// Konversi hasil dari suhu tertinggi dan terendah menjadi
Celsius
suhuTertinggi = ee.Number(suhuTertinggi).format('%.2f');
suhuTerendah = ee.Number(suhuTerendah).format('%.2f');
// Menampilkan hasil suhu tertinggi dan terendah di konsol
print('Suhu Tertinggi (°C):', suhuTertinggi);
print('Suhu Terendah (°C):', suhuTerendah);
// Fungsi untuk menambahkan legenda di peta
function addLegend() {var legend = ui.Panel({style:
{position: 'bottom-left',padding: '8px 15px'}});
  // Judul legenda
  var legendTitle = ui.Label('Kategori Suhu dan Luas
Wilayah (ha)', {fontWeight: 'bold',fontSize: '16px'});
  // Isi legenda dengan kategori suhu dan luas wilayah
  var legendItems = [
    {color: 'blue', label: 'Suhu Sangat Rendah (<20°C): ' +
luasSangatRendah.format('%.2f').getInfo() + ' ha (' +
persenSangatRendah.format('%.2f').getInfo() + '%)'},
    {color: 'green', label: 'Suhu Rendah (20-25°C): ' +
luasRendah.format('%.2f').getInfo() + ' ha (' +
persenRendah.format('%.2f').getInfo() + '%)'},
    {color: 'yellow', label: 'Suhu Sedang (25-30°C): ' +
luasSedang.format('%.2f').getInfo() + ' ha (' +
persenSedang.format('%.2f').getInfo() + '%)'},
    {color: 'orange', label: 'Suhu Tinggi (30-35°C): ' +
luasTinggi.format('%.2f').getInfo() + ' ha (' +
persenTinggi.format('%.2f').getInfo() + '%)'},
    {color: 'red', label: 'Suhu Sangat Tinggi (>35°C): ' +
luasSangatTinggi.format('%.2f').getInfo() + ' ha (' +
persenSangatTinggi.format('%.2f').getInfo() + '%)'}
  ];
  legend.add(legendTitle);
  legendItems.forEach(function(item) {var colorBox =
ui.Label({style: {backgroundColor: item.color,padding:
'10px',margin: '2px',width: '20px',height: '20px'}});
    var description = ui.Label(item.label, {padding:
'5px',fontSize: '14px'});
    var row = ui.Panel({widgets: [colorBox,
description],layout: ui.Panel.Layout.Flow('horizontal')});
    legend.add(row);});
```

```
  // Menambahkan legenda ke map
  Map.add(legend);}
// Menambahkan informasi suhu tertinggi dan terendah ke
peta
function addTemperatureInfo() {
  var temperatureInfo = ui.Panel({style: {position:
'bottom-right',padding: '8px 15px'}});
  var title = ui.Label('Informasi Suhu', {fontWeight:
'bold',fontSize: '16px'});
  var maxTempLabel = ui.Label('Suhu Tertinggi: ' +
suhuTertinggi.getInfo() + ' °C');
  var minTempLabel = ui.Label('Suhu Terendah: ' +
suhuTerendah.getInfo() + ' °C');
  temperatureInfo.add(title);
  temperatureInfo.add(maxTempLabel);
  temperatureInfo.add(minTempLabel);
  Map.add(temperatureInfo);}
// Ekspor peta LST 2010 ke Google Drive
Export.image.toDrive({image: lst2010,description:
'LST_Lombok_Timur_2010',scale: 1000,region:
lombokTimur,fileFormat: 'GeoTIFF'});
// Menambahkan legenda dan informasi suhu ke peta
addLegend();
addTemperatureInfo();
```