

Systematic Measurement of Temperature Change in Sumatra Island: 2000-2019 MODIS Data Study

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Received November 4, 2019; revised and accepted February 3, 2020

Abstract: Land surface temperature (LST) is one of the important factors in the physics of land surface processes to ensure the temperature change in the environment. Sumatra is one of the biggest islands in Indonesia that is suffering from deforestation. The objective of this study was to determine LST changes in Sumatra Island from 2000-2019. LST-day data for each region of Sumatra island were analyzed with cubic spline to see the seasonal pattern and get the LST changing value. The highest LST-day change was in the central region of Sumatra Island which was 0.3842 °C/decade (Z: 8.51, 95% CI: 0.296, 0.473). The lowest LST-day change was in the central north region of Sumatra Island which was -0.1574 °C/decade (Z: -3.022, 95% CI: -0.2596, -0.055). The overall LST-day change was 0.1621 °C/decade (Z: -3.022, 95% CI: -0.2596, -0.055).

Keywords: Land surface temperature; Sumatra; Climate change.

Introduction

Global warming is one issue that everyone is talking about recently. As a global issue, the evidence of global warming also needs to be proven by measuring the temperature change in the local and global scales area (Masson-Delmotte et al., 2019). The economy and social life are affected by climate change (Mishra et al., 2010). Further more, climate change has an impact on the environmental and health system (Marjuki et al., 2016; Mboera et al., 2011).

There was evidence that climate change gives an impact or relation to human vulnerability on diseases (Wu et al., 2016). Land Surface Temperature (LST)

plays an important part in monitoring climatological processes at regional to global scales (Li et al., 2013; Wongsai et al., 2017). The measurement of climatic change by LST on a local scale was so critical and commonly used (Luintel et al., 2019). LST is the temperature at the surface layer of land that measures between the atmosphere and material at the soil surface (Stroppiana et al., 2014). The most widely used LST data were the product of a moderate resolution imaging spectroradiometer (MODIS) where the source of the data was from NASA Earth Observation System (EOS) satellites Terra and Aqua, launched in 1999 and 2002 (Wongsai et al., 2017). The satellite sensors will assess LST four times a day. For Terra satellite, the first

assessment was at 10:30 and the second was at 22.30. Then, for Aqua satellite, the third was at 13:30, and the fourth was at 1:30. The data were in daily, eight-day and monthly LST data time series at two spatial resolutions (1 km and 0.05 deg. Climate model grids, CMG) (Wan et al., 2015).

The scientists stated that the world is warming (Arneth et al., 2019). On the other hand, a study was mitigated about the climate change in Southeast Asia, and it was predicted that the temperatures will fall 0.79 to 0.71°C in 2060 (Rasiah et al., 2018). A statement about warming or cooling in the large area was still arguable. Several factors were also thought to be the cause of the warming in a particular area such as the change in land cover, the alterations in forest function, and the increase in human and industrial populations (Longobardi et al., 2016).

Forest existences were the influence of the island temperature on a regional or global scale (Vadrevu et al., 2019). Sumatra Island was the largest of three islands that faced deforestation in Indonesia (Rijal et al., 2016). Forest conversion and climate change issues have fascinated the researchers all around the world (Brack, 2019). Thus, this study chooses Sumatra as an area of the study to measure the LST change in the regional area.

Materials and Methods

Study Area

This study was conducted in Sumatra Island. Sumatra Island is located from east longitude 95 to 106.20 east longitude and north latitude 6.0 to 6.20 south latitude (Figure 1). Forty-five subregions as a sample set were chosen to measure the LST change for Sumatra and were grouped into five regions.

As the pixel was the smallest information from an image, Terra Satellites used an area of 1 km × 1 km as the centre point to build a 3 km (above and below) × 3 km (left and right) and 7 km × 7 km dimensions as the result. This was also a consideration due to the sub-set order recommendation provided by MODIS, and it might hinder the spatial autocorrelation.

The sample points are located around parallels of latitude 105 pixels widths (95 km) apart. We assumed that the nine subregions in one region have the same parameter as in the nine subregions of the other regions, each comprising 49 pixels in a 7 × 7 array, covering the Sumatra island. We specify the latitude and longitude of its central pixel to download data for a subregion.

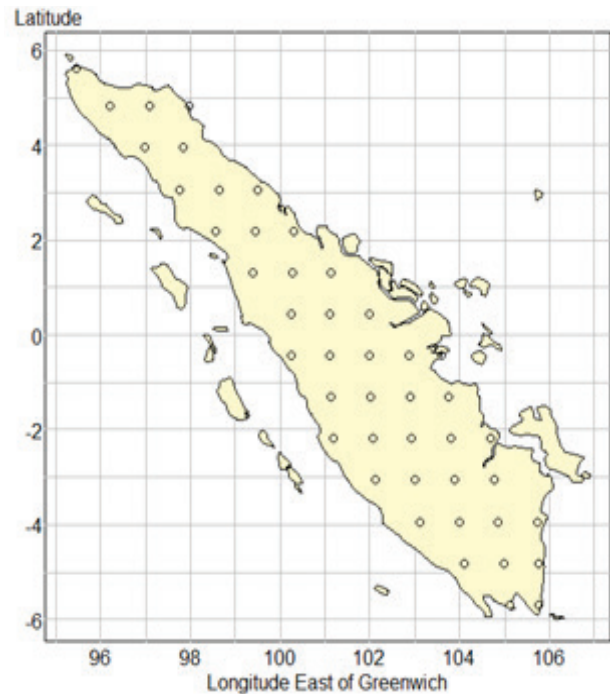


Figure 1: Sumatra area of study.

Data Source and Analysis

Data on daily LST on Sumatra island from March 2000 to November 2019 were used to investigate the change of daily LST. The LST data were freely downloadable from the MODIS database that contains average temperatures every eight days of clear sky for pixels each of area 0.859 km². The time-series trends and patterns of LST were analyzed using a cubic spline. The ARIMA models were used to analyze the time-series data and forecast the LST data, and the multivariate regression models were utilized to minimize the spatial and autocorrelation that was discovered in the ARIMA models.

LST data were the data from freely data sets of MODIS (<https://modis.ornl.gov>) (ORNL DAAC, 2018; Phan et al., 2018; Wan, 2008). The calculation of the exact location on Latitude and Longitude which is determined or converted by the Modland tile calculator tool in vertical tile, horizontal tile, line, and the sample must be completed to get the LST data. Without the correct and exact location in Latitude and Longitude, the page will not continue or will serve unneeded data. The range between the sample should be at the same range to decrease the spatial correlation.

MOD11A2 Terra LST data were the code for LST data on the next page of the website. Due to land climate components influenced by atmospheric and land processes, these data were only for land, and the area

with water body (ocean) was not available (Luintel et al., 2019; Wan et al., 2015). The analysis of this study was conducted with the R program (Team, 2018). The website give the resume of data that we downloaded, and choose the order, so the data set link is sent to our registered email. LST data must be ordered at a different time because the website only gave one option name of data in each order.

The data access order were sent into an email, and the data were provided in CSV format. The last step is processing and analyzing the data with the R program (Phan et al., 2018; Wan, 2008). LST data were from MODIS 8 days Tera LST (MOD11A2) at 0.05° spatial resolution. The original LST degree measurement was Kelvin which was then converted into Celsius.

After converting the data and managing the year form, we plotted the day temperatures in subregions with fitted cubic splines to see the trends of LST daily for a year from 2000-2019. We assumed that each subregion has constant seasonal variations and seasonal patterns for each day of the year within a year presented in a plot. Running a plot with a natural cubic spline is considered the most appropriate model that ensures the smooth periodicity. With natural cubic splines, one constructs a spline basis with knots at a fixed location throughout the data points (Yang et al., 2012). Choosing the location and number of parameter knots for smoothing the spline curve is a critical issue. Here, we used three models: linear, 4-knots spline, and 7-knots spline. Spline-smoothed seasonal patterns were subtracted to create a season-adjusted time series while using the autoregression model to estimate model curves adjusted for time series correlation.

Linear models were used to show variations and natural cubic splines to identify the seasonal patterns in LST during 2000-2019. The other way, multivariate regression models accommodate temporal and spatial variations in the effects of the covariates, including the intercept (Gamerman and Moreira, 2004). The variance-covariance matrix in multivariate regression is used to create confidence intervals of response variables in linear combinations. The increase in $^\circ\text{C}$ per decade will be estimated using the multivariate regression model.

We did not only calculate the LST-day increase in the region but also the Z score to see the LST-day change in sub-region. The increased category of sub-region was divided into five: increase with $z > 1.96$ (red), likely increase with $z > 1$ (orange), stable with $|z| \leq 1$ (green), likely decrease with $z \leq -1$ (ocean boat blue) and decrease with $z < -1.96$ (vivid blue). The regions were grouped in five which is increase (deep pink), likely increase (pink),

stable (vivid green), likely decrease (vivid cyan) and decrease (dark cyan). This shaded group was made to differentiate when depicting the plotting result.

Results and Discussion

Figure 2 depicts the LST change for 45 sub-regions (circle) and five regions (five shaded areas) in Sumatra Island. The day of LST is changed differently in the five regions: decreasing in the central north, increasing in the north, central, central south, and likely increasing in the south. This result was based on Table 1. Table 1 depicts 45 subregions LST day increase from 2000-2019. The plot of LST change for each sub-region was based on this result. The plot of LST change for each region was based on Table 2.

Table 1 depicts that the highest LST day change occurred in sub-region 22 ($1.114^\circ\text{C}/\text{decade}$). The lowest LST day change occurred in sub-region 14 ($-1.561^\circ\text{C}/\text{decade}$). The highest LST day change was in region 3 (central) and the lowest was in region 2 (central).

Table 2 depicts that the highest LST change was in the central region of Sumatra island with a value of $0.3842^\circ\text{C}/\text{decade}$ and Z value of 8.510 (95% CI 0.2957-0.4727). The lowest LST change was in the central north of Sumatra island with a value of $-0.1574^\circ\text{C}/\text{decade}$ and Z value of -3.022 (95% CI $-0.2596 - -0.0553$). The overall average was shown that the LST in Sumatra island was increasing $0.1621^\circ\text{C}/\text{decade}$ and, by using

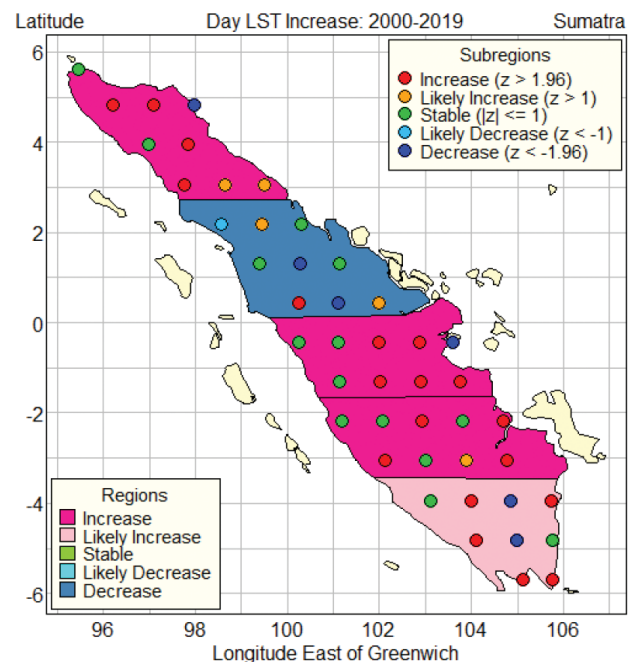


Figure 2: LST day increase ($^\circ\text{C}/\text{decade}$) 2000-2019 of Sumatra.

Table 1: The mean of LST day increase/decade and *p*-value for 45 sub-regions Sumatra island 2000-2019

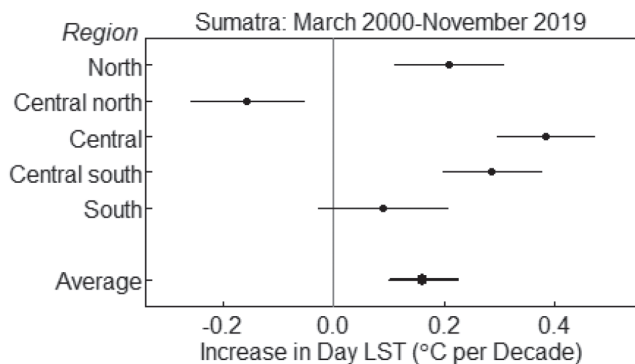
<i>Sub-reg</i>	<i>Increase</i>	<i>p-value</i>	<i>Sub-reg</i>	<i>Increase</i>	<i>p-value</i>	<i>Sub-reg</i>	<i>Increase</i>	<i>p-value</i>
1	-0.192	0.242	16	0.334	0.025	31	0.066	0.677
2	0.342	0.026	17	-0.579	0	32	0.886	0
3	0.641	0	18	0.314	0.075	33	0.358	0.004
4	-0.334	0.044	19	0.1	0.536	34	0.055	0.681
5	0.177	0.189	20	0.196	0.228	35	0.207	0.11
6	0.297	0.025	21	1.036	0	36	0.41	0.009
7	0.314	0.03	22	1.114	0	37	-0.113	0.388
8	0.363	0.05	23	-0.892	0	38	0.304	0.046
9	0.221	0.143	24	0.134	0.329	39	-0.711	0
10	-0.239	0.091	25	0.371	0.015	40	0.517	0
11	0.307	0.108	26	0.583	0	41	0.383	0.01
12	-0.176	0.483	27	0.678	0	42	-0.575	0.001
13	0.114	0.495	28	-0.083	0.449	43	0.213	0.254
14	-1.561	0	29	0.181	0.179	44	0.406	0.012
15	0.031	0.855	30	0.496	0.001	45	0.345	0.041

Table 2: LST day increase °C/decade and *p*-value for 45 sub-regions Sumatra island 2000-2019

<i>Region</i>	<i>Increase</i>	<i>95% CI (Confident Interval)</i>	<i>Z</i>
North	0.2084	0.1093 - 0.3075	4.123
Central north	-0.1574	-0.2596 - -0.0553	-3.022
Central	0.3842	0.2957 - 0.4727	8.510
Central south	0.2868	0.1971 - 0.3766	6.267
South	0.0885	-0.0283 - 0.2053	1.190
All region average	0.1621	0.1004 - 0.2238	

multivariate analysis, the z-value was 3.4136 (95% CI 0.1004-0.2238).

Figure 3 is a description of Table 2. This figure depicts that the LST day in four regions (North, central, central south and south) was increasing; only

**Figure 3: The Sumatra Island increase in Day LST confidence interval.**

one region (central north) was decreasing and the overall Sumatra island was increasing. A study shows that the deforestation in Sumatra was statistically increasing (Basyuni et al., 2018). The area of central Sumatra island was the most deforested area (Poor et al., 2019). This can be evidence that the occurrence of deforestation was considered affecting the increase of temperature ambient.

Cooling and increasing temperatures in an area and the factors that cause it is still a matter of debate (Easterling and Wehner, 2009; Neukom et al., 2019). A study states that the cause of a temperature increase in an area was due to changes in land cover, gas emissions, and an increase in human and industrial populations (Datta et al., 2017).

The previous study shows that the Sumatra area's surface temperatures have increased and this confirms the findings of this study (Musyayyadah and Vonnisa, 2019). This warming condition can be triggered by

several causes such as land cover changes (Mitraka and Chrysoulakis, 2016; Saputra and Lee, 2019). Land cover in Sumatra is a largely tropical rainforest and currently is experiencing massive deforestation (Goetz et al., 2012; Rijal et al., 2016; Saputra and Lee, 2019). Forest conversion can cause an increase in the temperature in the local region (Prevedello et al., 2019).

A temperature increase also occurred in areas with a small vegetation index (Sun et al., 2012). Area with small vegetation index (unhealthy vegetation area) or converted land cover area also affects LST change (Deng et al., 2018). A study illustrates that a low NDVI (Normalized different vegetation index) will result in a high LST (Rahmad et al., 2019). Contrarywise, if the NDVI was high, the LST tends to be low (Parveen and Ghaffar, 2019). These findings occur in the central part of the North Sumatra region.

Temperature changes that occur in Sumatra are still relatively small. A study shows that the increase in temperature of an area can be reduced if the converted-LULC (Land Use-Land Cover) area can be recuperated as formerly (forest) (Gogoi et al., 2019). It was expected that an LST increase can be affected or reduced by increasing NDVI (Cooper et al., 2017).

Conclusions

The increase in LST in Sumatra confirms that global warming is occurring in the local area (an island) of Sumatra. LST on Sumatra island was increasing 0.1621 °C/decade in the whole island (45 sub-regions and five regions). Further studies on a broader scale are urgently needed since this study only discovered the cooling phenomenon. Other factors such as land use-land cover (LULC) and NDVI can be taken into consideration for further studies. It will be a good issue to investigate the factor that affects the LST change.

Acknowledgements

The authors appreciations for The Thailand's Education Hub for the Southern Region of ASEAN Countries (TEH-AC), Universitas Airlangga and Prince of Songkla University Graduate School Research Grant.

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