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Abstract. Land Surface Temperature (LST) can be used as an indicator of measuring temperature change in the regions. The changing variation can be produced or affected by some factors such as elevation, land cover products, and Normalized Difference Vegetation Index (NDVI). This study aimed to investigate LST variation based on elevation, land cover products, and NDVI in the North Sumatra area, Indonesia. Land products satellite data between 2000 and 2018 were downloaded from the moderate resolution imaging spectroradiometer (MODIS) website. Multiple linear regression was used to find the patterns of LST variation. The highest LST variation was found in Evergreen Broadleaf (EB) forest and urban area with the average change 0.4 and 0.5 $^{\circ}$C/decade and the lowest was found in water surface area with the average change more than -1 $^{\circ}$C/decade. The overall mean of LST changing was -0.1 $^{\circ}$C/decade with r-square 31.4%. There was a unique LST variation in EB forest land cover when the elevation increased, the LST also increased from -0.4 to 0.5 ^{0}C/decade. The same condition also appears in Savannas and cropland/natural vegetation mosaic (Crop. Mos.). In conclusion, the changing of LST in North Sumatra was affected by elevation, land cover products, and NDVI.

1. Introduction

In recent years, climate change, particularly rising temperatures, is one of the important environmental problems facing the world today [1]. LST is the outer layer of temperature which is at the crossing point among superficial materials and the atmosphere [2]. LST is a satellite-based climate-related data that has an important part in controlling climatological processes, water stability at small to large-scale area and land surface energy interactions [3], [4].

The climate negatively affects human daylilies and environments [3]. This was represented in the long-term decreasing in the predominance of nutrition impairments, which slightly linked to extreme necessary events [5]. This was predominantly related to Southeast Asia since food production and security were at-risk sectors and Southeast Asia has a vital role as major exporter [6]. Since the 1950s, the tropics had become a source of enhancing interest among meteorologists because convective storms dominated the weather of the tropics. These develop mainly along the Intertropical Convergence Zone [1]. North Sumatra was one of the areas in Sumatra Island and it has tropic climate.

A study in Sumatra Island about land cover change (deforestation rate) shows that this island has the highest deforestation rate in Indonesia [7]. A study report that 70% of forests in Sumatra have been

destroyed since 1990 to 2010 [8]. Land degradation and deforestation in the North Sumatra area has been achieved 2.4 million hectares of land at risk [9]. Deforestation caused greenhouse gas emissions by 17% and believed as a factor of increasing the earth's temperature [10]. Thus, North Sumatra is selected to be a study area of whether the Land Surface Temperature (LST) was influenced by other factors namely land cover, NDVI, and elevation.

The elevation, land cover product, and normalized difference vegetation index (NDVI) were some potential determinants to analyze land surface temperature [11]–[13]. The high difference in land elevation has a significant effect on LST [14]. Remote sensing application in thermal detection has been applied in urban regions to estimate urban heat island, to threat land cover groups and as input for developing a model of urban surface-atmosphere exchange [15]. A study used correlation appraisals and multiple linear regressions to investigate the impacts of the structure and shape of land cover types on LST in Baltimore, Maryland, USA by considering Landsat Enhanced Thematic Mapper Plus (ETM+) image data [16]. It has been proposed that the effect directions of land cover variables on assessing LST were reliable throughout periods or seasons, although the significance of consequences, multifarious by periods or seasons, during summer were providing the strongest predictive ability and the weakest during winter [17].

Studies had been conducted to analyze the impact of the land cover on surface temperature and the effect of the extreme temperature in the land surface [18]. A study in the urban climate stated that NDVI and LST have no parallel value [19]. It means that in the high-temperature area has low NDVI and oppositely high NDVI is in the low-temperature area. Areas with high vegetation and water body have lower temperatures [20]. Some studies had been proposed to analyze the vegetation type and LST which had a negative correlation and associated with different land-use types [21], [22]. Therefore, this study considered elevation, land cover, and NDVI as an important factor to analyze LST in a tropical area, which is in North Sumatra. Moreover, this finding will confirm the existing phenomena occurring in the study region and favorable for the authority to set the environmental rehabilitation plans. Policymakers could use this study result to be focusing on a particular area of Sumatra that needs protection from increasing temperature and what caused it.

2. Materials and Methods

2.1. Study area

North Sumatra was selected as a study area. North Sumatra area was the northern part of Sumatra island and this land was between the Indian Ocean and the Strait Malacca. The border of on the northwest was Aceh and in the southeast, there were Riau and West Sumatra. This area stretches for at least 66.150 km² (refer to data-pixel). This area consists of the wetlands along the Strait of Malacca and Medan (the third-largest city in Indonesia) was located here. In the western and southern areas consisting of the plateau which was a stretch across the island of Sumatra. There is also Lake Toba, which located in the mountains, which was an ancient volcanic caldera. Most of the large islands around it on the west coast of the North Sumatra area were part of the North Sumatra province. We divided this area into super regions with a size of 11 regions in order to simplify the data obtained from the MODIS website. Only 6 super regions were selected for further analyses because from 10 super regions in the North Sumatra area, 4 of it has most areas connected to the sea (see Figure 1.)

2.2. Data source

LST, elevation, land cover, and NDVI data between 2000 and 2018 were downloaded from the moderate resolution imaging spectroradiometer (MODIS) website. LST data were extracted from MODIS 8-day Tera LST (MOD11A2) at 0.05° spatial resolution. These data are the average of the surface temperature clear sky condition, and elevation data was extracted from the United States geological survey (https://earthexplorer.usgs.gov/) data [23]–[25].

MODIS land cover dataset (MCD12C1) and MODIS NDVI dataset (MOD13Q1) provide land cover data annually from 2000-2018 at a spatial resolution of 0.05°. Land cover dataset contains 17 land cover

classes, namely evergreen needleleaf forest, evergreen broadleaf (EB) forest, deciduous needleleaf forest, deciduous broadleaf forest, mixed forest, closed shrublands, open shrublands, woody (W) savannas, savannas, grasslands, permanents wetlands, croplands, urban and built-up, cropland/natural vegetation mosaic (CropMos), snow and ice, barren or sparsely vegetated and water bodies. These were defined by the International Geosphere-Biosphere Programme classification [26], [27]. In this study, MODIS data from 1,125 sub-regions covered the North Sumatra area for the years 2000-2018 were collected. Land cover was simplified into 9 categories of land cover (evergreen broadleaf forest, woody savannas, savannas, grassland, permanents wetlands, croplands, urban, cropland/natural vegetation mosaic, and water) by aggregating the small percentage that has same characteristics.

Sumatra super regions contain 70 super regions. Each super-region consists of 25 regions with a size of 105 km × 105 km. Each region consists of 9 sub-regions with a size of 21 km × 21 km. Each sub-region has a size of 7 km × 7 km. Six super regions of the North Sumatra were chosen for statistical analysis which was super regions 8, 9, 10, 13, 14 and 15. Super regions 11 and 12 were not included in the analyses as most of the area is water (see Figure 1). 66.150-pixel data with 855 observations from 2000-2018 was used for this study for 6 super-region.

NDVI pattern grouped decide by using recursive partitioning decision tree and elevation also grouped for made the graph result readable. Elevation was categorized into 9 meters above sea level (MASL): 1. 0-14 MASL; 2. 15-29 MASL; 3. 30-69 MASL; 4. 70-149 MASL; 5. 155-349 MASL; 6. 350-599 MASL; 7. 600-899 MASL; 7. 600-899 MASL; 8. 900-1199 MASL; 9. 1200+ MASL. Land cover was simplified into 9 categories of land cover by aggregating the small percentage that has the same characteristics. The NDVI was categorized into 2 groups: 0.85 or more and less than 0.85. The range of Index values was from -1.0 to 1.0, but vegetation index values typically range between 0.1 and 0.7. Healthy vegetation cover has high index value and value near zero was an index for the area that reflects a similar level of near-infrared and red such as bare soil and rock. A negative value was for cloud, water, and snow which is the opposite of vegetation[28]. ARIMA coefficient was used in this study to take out the autocorrelation of LST-day data. All of the analysis, graph, and map was created by using the R program [29].

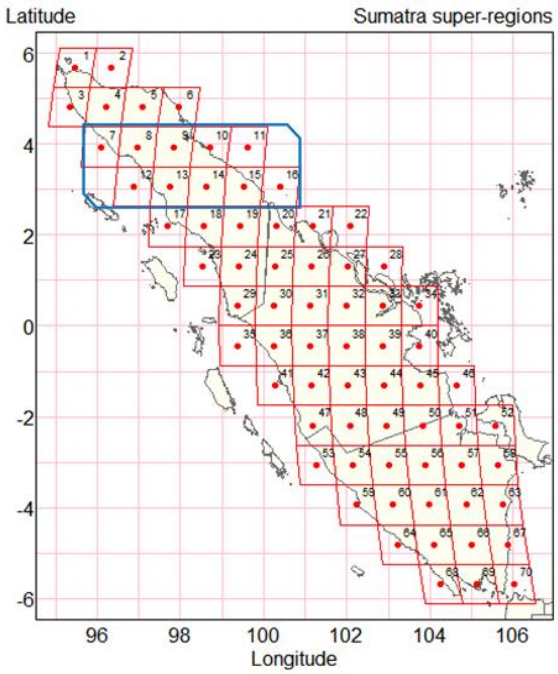

Figure 1. Super regions of Sumatra and North Sumatra with the center of latitude and longitude

3. Results and Discussion

This study consisted of 9 land cover products. The biggest area was the evergreen broadleaf forest (EB forest) accounted for 59.5% of land covers. The smallest area was water accounted for 1.2% of land covers (See figure 2). The other land cover areas with similar characteristics and small areas were aggregated into the same land cover area. The overall r-square was 31.4%. This means that elevation, land cover and NDVI influenced LST by 31.4%, and remained 68.6% affected by the other factors. Based on the result of this study, NDVI indicated vegetation for estimating LST in urban heat islands. But the results showed that land cover classes were not effective in some islands as we can see the correlation with LST [30]. The other study revealed that in highland areas, spatial heterogeneity in LST is also high due to surface landscape, land cover, superficial solar radiation, and more components [31].

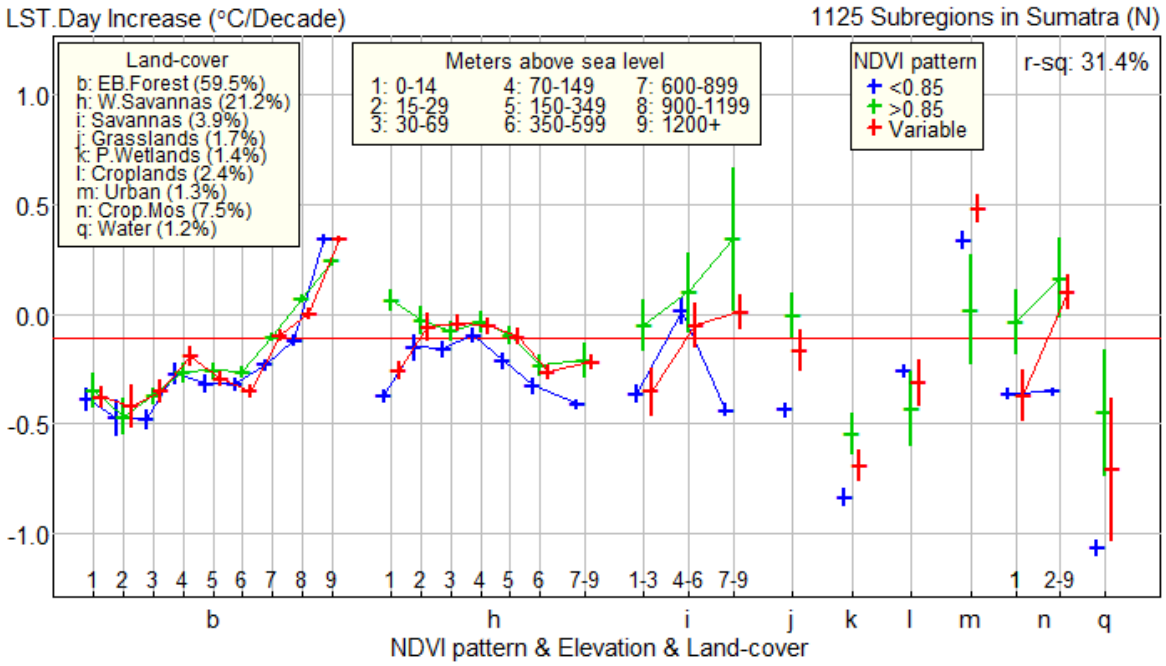

Figure 2. The LST day increase per decade (˚C/decade) by NDVI, elevation and land cover of North Sumatra in 2000-2018

The highest increasing day LST was found in EB forest and in an urban area with 0.4 and 0.5 ˚C/decade. Both areas covered 59.5% and 1.3% of the North Sumatra area. The elevation of more than 1200 MASL with NDVI<0.85 happened in the EB forest. Changes in forest land cover conditions were a major factor in climate change in recent times [32]. Another study reported that land cover modification (deforestation) triggered major heating in the tropical area but forestation generated an opposing effect on the temperature change [26]. A study mentioned that on the local scale of the tropical area, deforestation and forestation obviously affected the changing of LST [33].

The water area covered 1.2% of land covers had the lowest LST day increase (˚C/decade) approximately – 1 ˚C/decade. The water surface region was cooler in comparison with the other surface forms. A study in Turkey stated that the water area gives an effect on the land surface temperature around the water region[34]. The temperature changing also give significant influence in the environment (flora and fauna) and region topography related LST[35]. Due to water lets the light going profound into the deep flouting heat transmission during the day resulting in LST was in low value [36].

The LST variation of NDVI less than 0.85 was lower than the LST variation of NDVI at more than 0.85. It's mean that less vegetation in that area, the LST was decreasing at some level of elevation. The different condition was in urban and croplands, the LST change increased when NDVI less than 0.85. It's mean that less vegetation in that area, it had a higher temperature. A study in the urban developed

area in China had the highest LST [13]. The possible reason for decreased land surface temperature was because of the body water [37]. As we know that in the north Sumatra area there are Toba Lake that has a wide region water area.

Conclusions

Elevation, land cover changes and NDVI have related to LST Day Increase in the North Sumatra area that indicated the highest LST day increased was found in EB forest and urban area. Changing of elevation, land cover and NDVI contribute to the LST day increased. Although the overall characteristics of air temperature variation in north Sumatra of Indonesia are in the tolerable range, persistent monitoring is necessary.

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Conflict of Interest

The authors declare no conflict of interest. This research is original research, there is no potential conflict of interest.

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