The LST and NDVI Before and After Earthquake of West Celebes 2021 Using Terra/Aqua MODIS Satellite Image

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Abstract Earthquakes are one of the natural disasters that can cause quite a significant impact on the surrounding environment. This research aims to analyze changes in Land Surface Temperature (LST) and Normalize Difference Vegetation Index (NDVI) before, during, and after the earthquake in West Sulawesi in 2021 using Terra/Aqua MODIS satellite image data. Terra/Aqua MODIS satellite image data is

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processed through the Google Earth Engine (GEE) online software. The results of the analysis show that the area showed low LST values and high vegetation growth rates before the earthquake. When an earthquake occurs, the LST value increases drastically, and the NDVI value decreases significantly. The condition indicates the changes in environmental conditions and damage to vegetation due to earthquake shocks. After the earthquake, the LST value decreased again, and the NDVI value increased, indicating the area's vegetation recovery.

Keywords Earthquakes · LST · MODIS · NDVI · Satellite

1 Introduction

Earthquakes are one of the natural disasters that can cause quite a significant impact on human life and the surrounding environment. The West Sulawesi region, Indonesia, experienced a large earthquake on Friday, 15 January 2021, with a magnitude of 6.2. The center of the earthquake (epicenter) was located in the sea at coordinates 2.97° S and 118.99° E, northeast of Majene (with an epicenter depth of 21 km). The earthquake caused damage and changes in various aspects of life, including the surrounding natural environment [1].

After an earthquake occurs in an area, analyzing changes in land surface temperature and vegetation index is essential. These changes can provide insight into the impact of earthquakes on the environment, including areas directly affected by earthquake shocks and long-term impacts on vegetation and the surrounding environment. One way to monitor and analyze earthquake-related environmental changes is to utilize satellite imagery technology. Satellite imagery has been widely used as a valuable data source in research on natural disasters, including earthquakes. Terra/Aqua MODIS (Moderate Resolution Imaging Spectroradiometer) satellite imagery can obtain land surface temperature data and vegetation indices [2, 3].

Land surface temperature (LST) measures the Earth's surface, including land, sea, and vegetation. Land surface temperature measurements are essential in understanding climate change and analyzing the impact of natural disasters, including earthquakes. Terra/Aqua MODIS satellite imagery can accurately retrieve land surface temperature information through remote sensing [3, 4].

The Vegetation Index is a parameter that measures the level of growth and health of vegetation in an area. One vegetation index often used is the Normalized Difference Vegetation Index (NDVI) [5, 6]. NDVI measures the reflectance of the electromagnetic spectrum's red and infrared regions and indicates the chlorophyll content and presence of living vegetation in the region. NDVI analysis of Terra/Aqua MODIS satellite images can provide information about the distribution and changes in vegetation before and after an earthquake [7].

This research uses Terra/Aqua-MODIS satellite imagery because it has more spectral wavelengths (spectral resolution), more precise land coverage (spatial resolution), and more frequent observation frequencies (temporal resolution) [8]. The wave range

in its channels is very close to producing better and more accurate parameter information. Satellite image data can be processed using cloud computing-based spatial data processing software. Cloud-based processing can be done via Google Earth Engine (GEE), accessed for free/open source [9].

2 Methods

This research generally aims to analyze changes in vegetation indices and land surface temperatures in the West Sulawesi region in response to earthquakes. Land surface temperature and vegetation index were analyzed on MODIS terra/aqua data covering areas in West Sulawesi. In Fig. 1, the analyzed area is marked with a black circle. The vegetation index is an image transformation method based on spectral data, which is widely used not only for observing plants but has also been modified for various purposes, such as soil background effects in vegetation analysis [5–7]. They are using Terra/Aqua MODIS satellite imagery processed via the Google Earth Engine (GEE) online software. GEE is a spatial data processor based on cloud computing, which can be accessed for free/open source. With GEE, satellite image processing is no longer done conventionally; downloading and processing, nevertheless, by arranging programming [9].

Determination of the LST in the GEE uses the formula of the radiative transfer equation,

$$L_\lambda = M_L \times Q_{cal} + A_L \tag{1}$$

Fig. 1 The location of West Sulawesi Province on the map of the Republic of Indonesia is marked with a circle (*Source* Geospatial Information Agency)

The L_λ, M_L, Q_{cal}, and A_L parameters represent spectral radiation at the top of the atmosphere (ToA), the rescaling factor of the thermal band, thermal energy, and the constant value of the thermal band, respectively. The spectral radiation value is then converted into brightness temperature by referring to the metadata of each respective dataset for satellite imagery. The brightness temperature value can be used as a reference for LST. The conversion of spectral radiation values refers to

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \tag{2}$$

Here, T is the temperature value in Kelvin units, K_2 and K_1 are the calibration constants obtained from metadata, and L_λ is the spectral radiation value from the Eq. (1) [10]. Furthermore, using the formula, the NDVI involves the red (RED) and near-infrared (NIR) bands.

$$NDVI = \frac{NIR + RED}{NIR - RED} \tag{3}$$

The NDVI value below 0 indicates a water body, 0–0.2 represents built-up land with minimal vegetation density, while 0.2–0.4 indicates a mixed vegetation area [5–11].

Analysis of changes in vegetation and temperature was carried out by measuring Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). Each variable was processed in the period before the 2020 earthquake, during the 2021 earthquake, and after the 2022 earthquake. After obtaining the Terra/Aqua-MODIS NDVI and LST satellite image data, the next step is to visualize the image into a map in PNG format in GrADS software [3].

3 Results and Discussion

3.1 Normalized Difference Vegetation Index

NDVI is a vegetation index that describes the level of greenness of plants in an area. The range of NDVI values ranges from 0 to 1, where a value of 0 indicates that the area is non-vegetated, and a value of 1 indicates that the area has maximum vegetation. In this research, the vegetation index is used to find out information about the distribution and changes in vegetation before, during, and after the earthquake.

Figure 1 shows the image processing results showing changes in NDVI (Normalized Difference Vegetation Index) values in areas affected by the earthquake in West Sulawesi. Before the earthquake, the NDVI value increased or showed a high value, which indicates a good level of vegetation growth and health. Before the earthquake, the area has environmental conditions supporting lush vegetation growth.

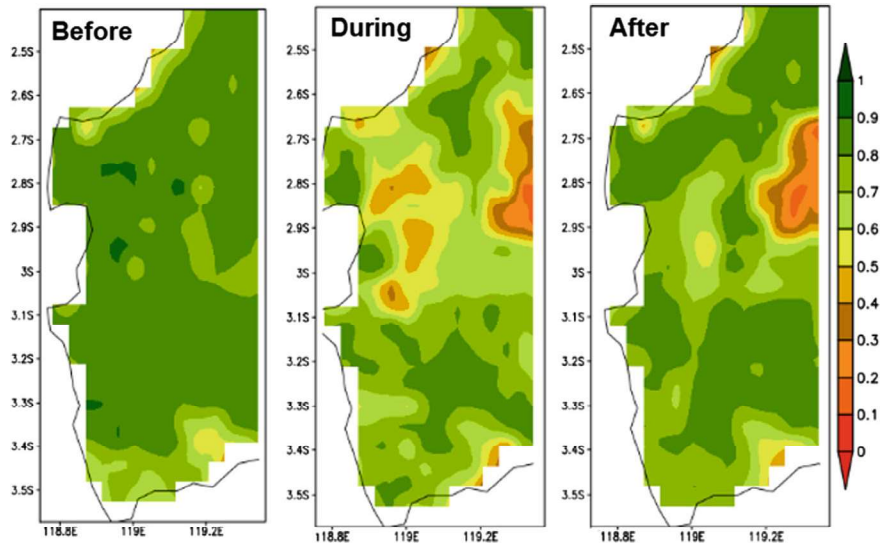

Fig. 2 Average NDVI distribution before, during, and after the 2021 earthquake in several areas in West Sulawesi Province

However, when the earthquake occurred (during), NDVI values decreased drastically, indicating a decrease in the area's growth rate and the health of vegetation. The decline can be caused by vigorous shaking and ground movements due to earthquakes, which cause damage to vegetation and disrupt environmental conditions that previously supported good vegetation growth [11].

After the earthquake, the NDVI value again increased or reached a high value. Several factors can explain this. First, after the earthquake, the area may have naturally experienced natural regeneration or through environmental restoration efforts by the community or government. Second, natural adaptation processes can also contribute to the region's vegetation recovery. However, vegetation growth rates may have yet to fully recover to pre-earthquake conditions [12] (Fig. 2).

3.2 Land Surface Temperature

Figure 3 shows the image processing results showing changes in LST (land surface temperature) values in areas affected by the earthquake in West Sulawesi. LST can be defined as the average temperature of different types of object surfaces. The temperature value is derived from the MOD11_L2 plot product using bands 31 and 32 with the band name LST_Day_1 km with a resolution of 1 km. Before the earthquake, the LST value showed a low value, indicating a relatively cold ground surface temperature. It can be explained by several factors, such as climate conditions and land use

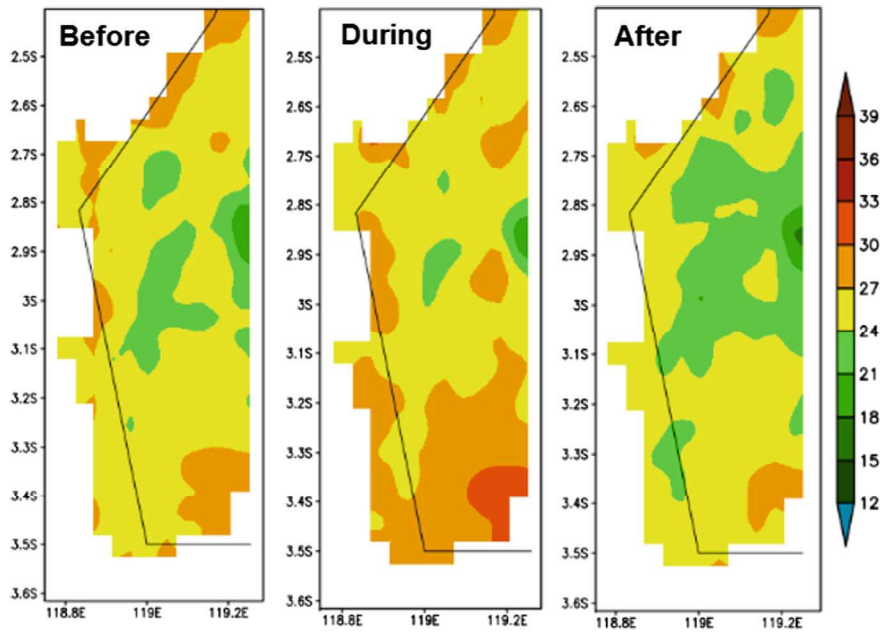

Fig. 3 Average LST distribution before, during, and after the 2021 earthquake in several areas in West Sulawesi Province

before the earthquake. Areas with lush vegetation or sufficient vegetation cover can cause a decrease in ground surface temperature before an earthquake [10].

However, when the earthquake occurred, the LST value increased significantly, indicating increased ground surface temperature. This increase can be caused by several mechanisms, including seismic activity, which can cause the release of heat energy to the ground surface, rock movement, and disturbance of soil layers. Earthquake shocks can also cause a decrease in vegetation or damage to vegetation, thereby reducing the ability of vegetation to absorb heat from the ground surface.

After the earthquake, the LST value decreased or reached a low value again. This decline could be caused by several factors, including the natural recovery process after the earthquake, vegetation adaptation to environmental changes, and perhaps also due to post-earthquake environmental restoration or rehabilitation efforts.

3.3 Relationship Between LST and NDVI

The relationship between LST and NDVI provides essential implications for understanding the impact of earthquakes on the environment and vegetation. This research shows that earthquakes can cause significant changes in environmental conditions, including land surface temperatures and vegetation growth rates. Understanding this

relationship can help in natural disaster mitigation efforts and adaptation planning to face potential disasters in the future. Figures 4, 5, and 6 show the relationship between NDVI and LST before, during, and after the 2021 West Sulawesi earthquake.

In the period before the earthquake, the graph shows low LST values and high NDVI values. The period during the earthquake showed a decrease in NDVI values due to seismic activity, which indicated vegetation damage and a decrease in vegetation growth rates. In the period after the earthquake, the graph shows a decrease in LST values and an increase in NDVI values. A decrease in the LST value indicates

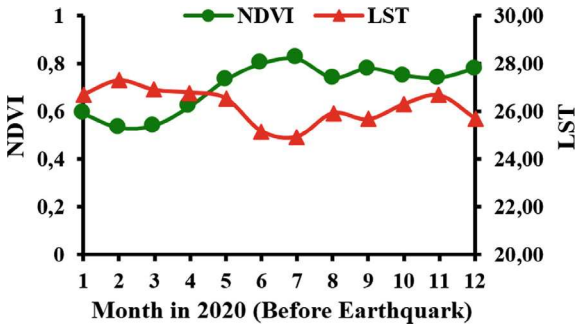

Fig. 4 Relationship between NDVI and LST before the earthquake

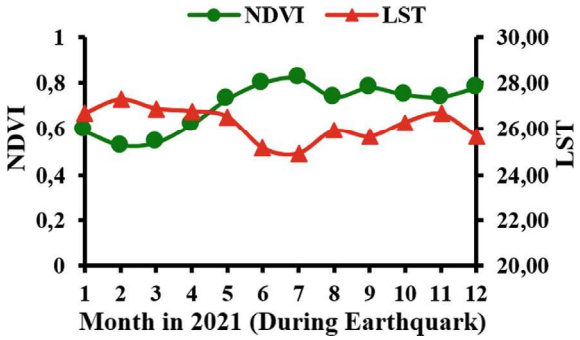

Fig. 5 Relationship between NDVI and LST during the earthquake

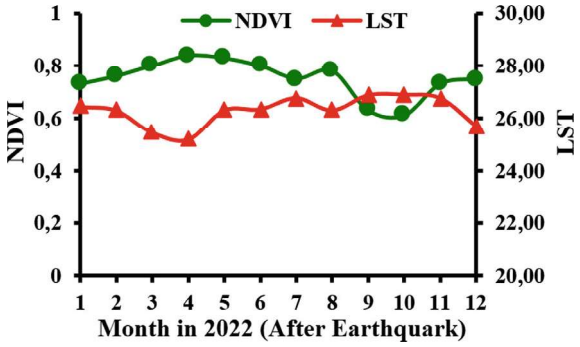

Fig. 6 Relationship between NDVI and LST after the earthquake

natural recovery or adaptation in the area, with the implementation of vegetation regeneration processes or post-earthquake environmental restoration efforts.

The analysis of the relationship between LST and NDVI shows that the greater the NDVI value, the lower the LST, and vice versa [6]. This analysis also shows the importance of vegetation recovery after an earthquake. Vegetation is indispensable in maintaining ecosystem balance, reducing soil erosion, and mitigating the impacts of climate change. Therefore, vegetation restoration is one of the priorities in environmental rehabilitation efforts and ecosystem recovery after a disaster [11, 12].

4 Conclusions

The effects of the earthquake in West Sulawesi in 2021 have been analyzed from various perspectives. In this research, an analysis was carried out on changes in the average normalized difference vegetation index (NDVI) and land surface temperature (LST). Both parameters were analyzed using Terra/Aqua MODIS satellite imagery processed via the Google Earth Engine (GEE) online software. Each variable was processed in the period before the 2020 earthquake, during the 2021 earthquake, and after the 2022 earthquake. The relationship between LST and NDVI provides essential implications for understanding the impact of earthquakes on the environment and vegetation. Based on the research, there is an inverse relationship between LST and NDVI. It indicates that the earthquake caused significant changes in environmental conditions, resulting in increased surface temperatures and decreased vegetation growth rates. So, efforts to rehabilitate the environment and restore vegetation become one of the priorities to rehabilitate the environment and restore ecosystems after a disaster.

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