Penggunaan Citra Satelit Suhu Inframerah dalam Kasus Gempa Bumi di Donggala, Indonesia

Thermal Infrared Satellite Imagery Application in Earthquake Case Activity in Donggala, Indonesia

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ABSTRAK - Penggunaan citra satelit termal infrared telah beberapa kali digunakan dalam mendeteksi aktivitas gempa bumi di beberapa wilayah di dunia. Penggunaan citra satelit termal dalam mendeteksi aktivitas gempa bumi didasarkan oleh adanya anomali termal yang dihasilkan dari tekanan panas *(heat stress*) dari kegiatan tektonik di wilayah hiposentrum gempa. Penelitian ini bertujuan untuk mengidentifikasi karakteristik termal sebelum dan sesudah gempa Donggala, Sulawesi Tenggara dengan menggunakan algoritma *land surface temperature* (LST) pada band TIRS citra Landsat 8. Hasil dari penelitian ini menunjukkan adanya korelasi antara karakteristik termal dengan aktivitas seismik yang diakibatkan oleh *heat stress* tektonik di wilayah Donggala. Studi ini menunjukkan adanya kenaikan suhu yang cukup tajam pada lima hari sebelum terjadinya gempa dan penurunan suhu satu bulan setelah terjadinya gempa di Donggala.

Kata kunci: gempa bumi, anomali inframerah termal, landsat 8

ABSTRACT *- The utilization of thermal infrared satellite imagery has been used several times for detecting the seismic activities across the world. The using of thermal satellite imageries for detecting the earthquake activities was based on the thermal anomalies presence that resulted from the heat stress produced by tectonic movement in hypocentrum area. Therefore, this research aims to identify the thermal characteristic prior and post the earthquake phenomenon that occurred in Donggala, Central Of Sulawesi by using the land surface temperature (LST) algorithm in TIRS band Landsat 8 imagery. The result show the presence of correlation between thermal characteristic and seismic activities that caused by tectonic heat stress in Donggala area. This study show the presence of thermal increasing sharply in five days prior to the Donggal earthquake evidence and thermal decreasing after the mainshock evidence..*

Keywords*: earthquake, thermal infrared anomalies, landsat 8*

1. INTRODUCTION

There is a long, sometimes controversial history of research relating earthquake precursors. Among such studies, many relate to possible thermal anomalies seen prior to large seismic event. (Pergola *et a*l., 2010). Early reports of possible air temperature variations related to seismic activity are detailed by Milne (1886), but the first attempts at measuring potential precursory Land Surface Temperature (LST) phenomena did not appear until the 1980s when Wang and Zhou (1984) claimed himself to have identified soil temperature anomalies prior to the 1976 Chinese Tangshin Earthquake (Blackett *et al*., 2011). The use of satellite technologies in remote sensing in recent years takes place in pre and post monitoring of earthquakes, especially in monitoring thermal anomalies before the earthquake (Kavlan and Avdan, 2017). The pressure before the occurrence of earthquakes can be represented by thermal anomalies or an increase in Land Surface Temperature (LST) (Saraf *et al*., 2009). The first applications of satellite data for earthquake exploration were initiated in the ‘70s, when active faults were mapped on satellite images (Tronin, 2010). According to limited infrared remote studies, there is abnormal radiation anomalies before great earthquakes, which is a natural phenomenon that happened during the earthquake process (Wei *et al*., 2013). While in the case of volcanic eruption, there is direct influx of heat through magma denting the surface of the Earth, its association with earthquakes has raised some fundamental questions, like the mechanism of transfer of heat from the focal region of earthquakes to the surface of the earth to generate thermal anomaly (Prakash and Srivastava, 2015).

Thermal infrared remote sensing detects the thermal condition on the ground surface by measuring the infrared radiation of earth atmosphere system, and we can utilize this thermal condition to capture the earthquake precursor information, which can predict the location and time of earthquake occurrence over *Ms*5.5 on a one month to half-year scale (Zhang *et al*., 2017). Thermal anomaly is generally measured through infrared sensors in advanced very high resolution radiometers of remote sensing satellites, but surface weather observations are also used to support or validate the inference (Prakash and Srivastava, 2015).

The physical link between observed anomalies and earthquakes has not been established so far, however, and the main reason can be tracked back to methodological shortcomings in existing literature (Jordan *et al.*, 2011). Definitions of what is actually an earthquake related thermal anomaly very among researchers and among different methodologies. Observed anomalies also seem to differ for the same earthquake. They may appear a few hours to a few years prior to an earthquake, and they might reappear shortly after an earthquake (Pavlidou *et al*., 2019).

The objective of this study is to analyze the relationship between the thermal anomalies that detected by thermal satellite imagery and earthquake evidence in Donggala, Central of Sulawesi, Indonesia at September 28th, 2018 by magnitude of 7,4 Mw. The thermal band of Landsat 8 Imagery was used to obtain the thermal anomalies anomalies information around Donggala area using LST algorithm.

2. METHOD

2.1 Study Area

This research was conducted in Donggala, Central of Sulawesi, Indonesia (**Figure 1**) which had been struck by strong earthquake (7,4 Mw) on 28th September, 2018 and caused tsunami in Palu area with wave up to 6 m. The epicenter of the quake is located 27 kilometers northeast of Donggala, at a depth of 10 km.

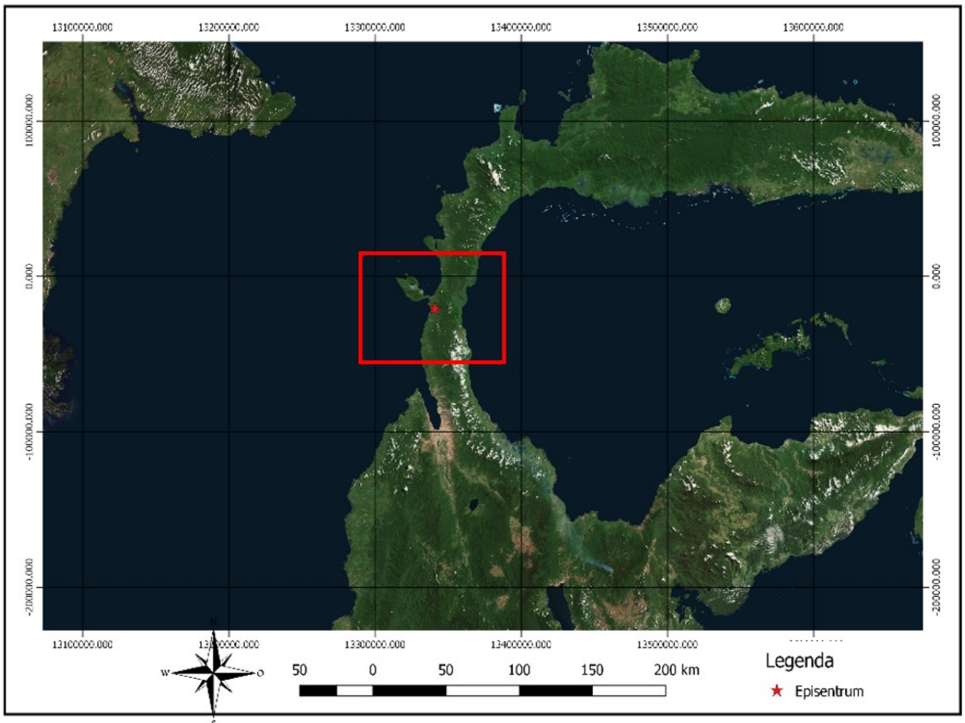

Figure 1. Study area that located in Donggala, Central of Sulawesi, Indonesia
(Source: Data processing)

2.2 Data Processing

Seven satellite imageries from Landsat-8 TIRS were downloaded from the USGS web page. The utilization of Landsat 8 TIRS imageries with range of temporal aims to identify the temperature change over the years toward the earthquake shockwave. The imageries were collected which captured the Donggala area several years before and several months before and after the main shock. The first image was collected on

24th June, 2014, approximately 4 years before the main shock. The second pair of images was collected on 13th July, 2015, 3 years before the main shock. The third pair of satellite image images was collected on 3rd October, 2016, 2 years before the main shock. The fourth imagery was captured about one year before shockwave on 7th November, 2017. Meanwhile, the sixth and seventh imageries were collected approximately several months before the main shock (2nd May 2018 & 25th September 2018). In addition, the last imagery was collected after the main shock on 25th October 2018. **Table 1** show the details about imageries that used in this research.

Table 1. Details of imageries that used in this study
(Source: Data processing)

Sensor	Date	Row	Path	Cloud Cover (%)
Landsat 8	06/24/2014	115	60	2.38
Landsat 8	07/13/2015	115	60	16.73
Landsat 8	10/03/2016	115	60	21,94
Landsat 8	11/07/2017	115	60	37.45
Landsat 8	05/02/2018	115	60	24.06
Landsat 8	09/23/2018	115	60	15.71
Landsat 8	10/25/2018	115	60	11.40

2.3 Method

LST is one kind of data that can be derived from thermal band of imageries. In remote sensing, LST can be defined as the average of of surface temperatures that visualized in pixel scale with several different surfaces type (Bakry *et al*., 2011). LST can be processed by utilizing Landsat 8 TIRS band by changing the pixel value/digital number (DN) to radiance value by using following formula:

$L\lambda = M \times QCAL + A$ ....(1)

where:

$L\lambda$ = radiance spectral ($wm^{-2}sr^{-1}\mu m^{-1}$),

QCAL = digital number (DN), *M* = radiance factor multiple value,

A = radiance factor adding value.

Then, the radiance value converted to temperature value (Kelvin) by following formula:

$T=K2/ln((K1/L\lambda)+1)$ ....(2)

where:

T = temperature value (Kelvin),

K1 = calibration value thermal band 1,

K2 = calibration value thermal band 2,

Lλ = radiance spectral thermal band.

To obtain the celcius value, we can change the Kelvin value to Celcius value by following formula:

$T (°C) = T (°K) - 272.15$ ....(3)

3. RESULTS AND DISCUSSION

Figure 2 shows the spatial change of LST around the Donggala earthquake epicentrum on 24th June 2014, 13th July 2015, 3rd October 2016, 7th November 2017, 2nd May 2018, 23rd September 2018, and on 25th October 2018. From the map, it can be noticed that the LST in epicentrum point in 2014 and 2015 were varying between 22-27 ^{O}C. The LST around epicentrum point on 24th June 2014 based on Landsat 8 TIRS imagery captured was about 22,8 ^{O}C and went up into 26, 46 ^{O}C on 13th July 2015. Meanwhile, the LST on 3rd October 2016, 7th November 2017 and on 2nd May 2018 showed anomalies value, in fact plummeted into

18,47 ^{O}C on 3rd October 2016, 19,82 ^{O}C on 7th November 2017, and 10,82 ^{O}C on 2nd May 2018 and show negative results. It estimated that the influence of thin cloud could affect the temperature information of Donggala in this scene and caused these anomalies. However, positive result shown the change of LST on 23rd September 2018, five days before main shock, which increase into 25,7 ^{O}C and indicated a heat stress prior to earthquake wave in this period. In addition, the LST on October 25th 2018 started to went down into 25,3 ^{O}C and indicated the decreasing of thermal heat stress. However, the imageries appeareance were distracted by the presence of thick cloud visualized by green area. It also the reason of the use of tight temporal imageries series to identify the temperature change in Donggala.

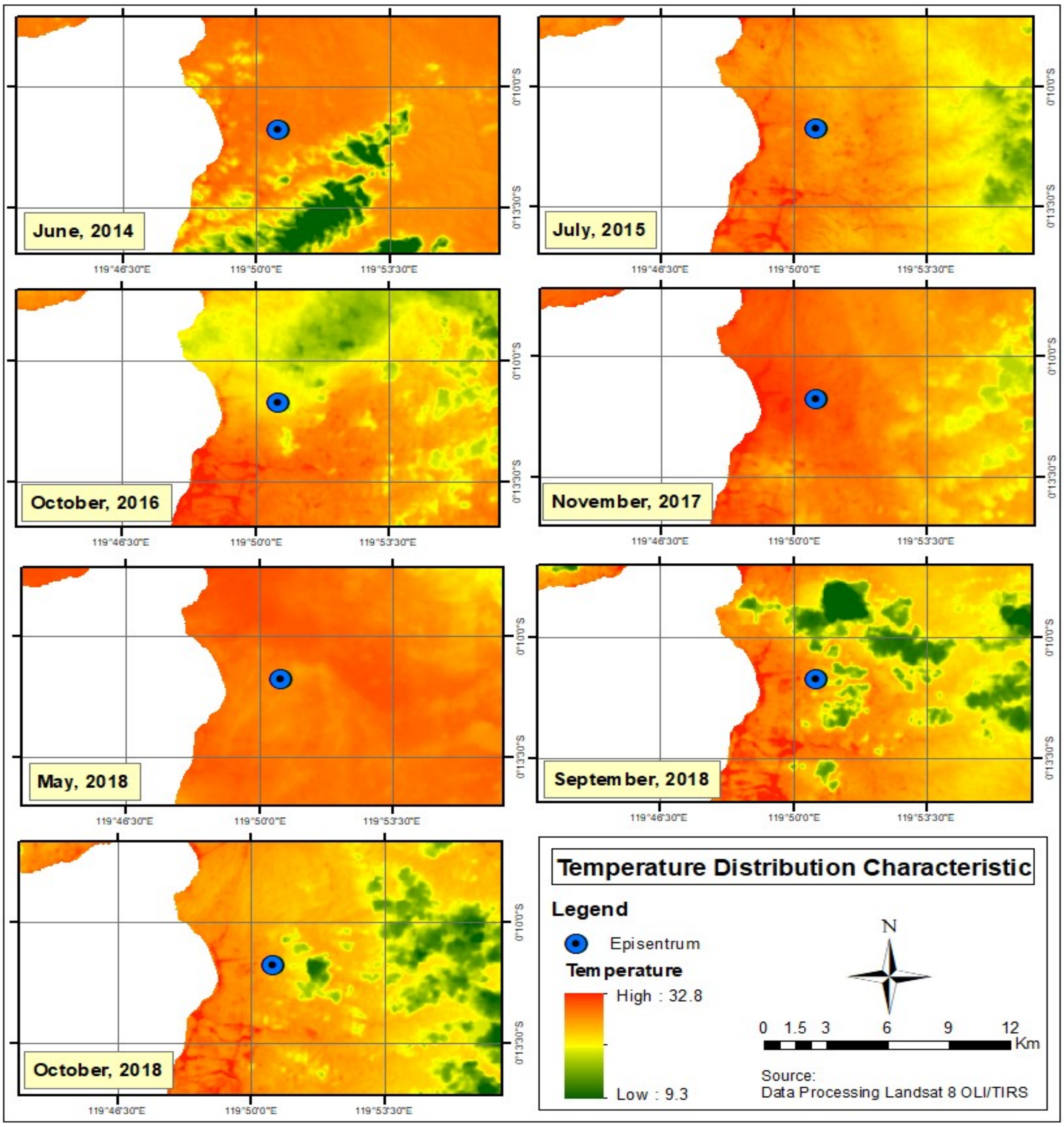

Figure 2. The Temperature Change Around Earthquake Epicentrum
(Source: Data processing)

Although it is hard to connect any thermal anomalies with an earthquake, studies have shown that most of the times thermal anomalies appear 7-14 days before the event and disappear few days after the event (Kavlan and Avdan, 2017). **Figure 3** shows the positive result that visualizes the increasing of LST before the main shock and the plummeted of LST after the main shock. The temperature climbed significant from 2nd May 2018 to 23rd September 2018, and dropped on 25th October 2018. We also find that a large-scale thermal infrared anomaly area was showed up in the west and southwest of earthquake epicentrum about 5 days before the earthquake and decreased after the earthquake in 25th October 2018. To sum it up, it can be noticed that there was relationship between the earthquake evidence (7,4 Mw) on 28th September 2018 with the LST increasing in Donggala and the decreased LST after the earthquake on 25th October 2018.

Nevertheless, we also can find that the trend of temperature change and its relation towards the earthquake evidence still hard to understand. According to **Figure 3**, the temperature was climbing massively 4 years before the earthquake and then it was continue decreasing until 2nd May 2018. Currently, the judgment of earthquakes based on thermal infrared temporal-spatial parameters is empirical and the prediction reliability on earthquake occurrence time and location is high, and the judgment on these two key elements is the emphasis in the whole tracking process (Zhang *et al*., 2017). It is making clear that the utilization of thermal infrared for forecasting the earthquake evidence still need further exploration in Indonesia.

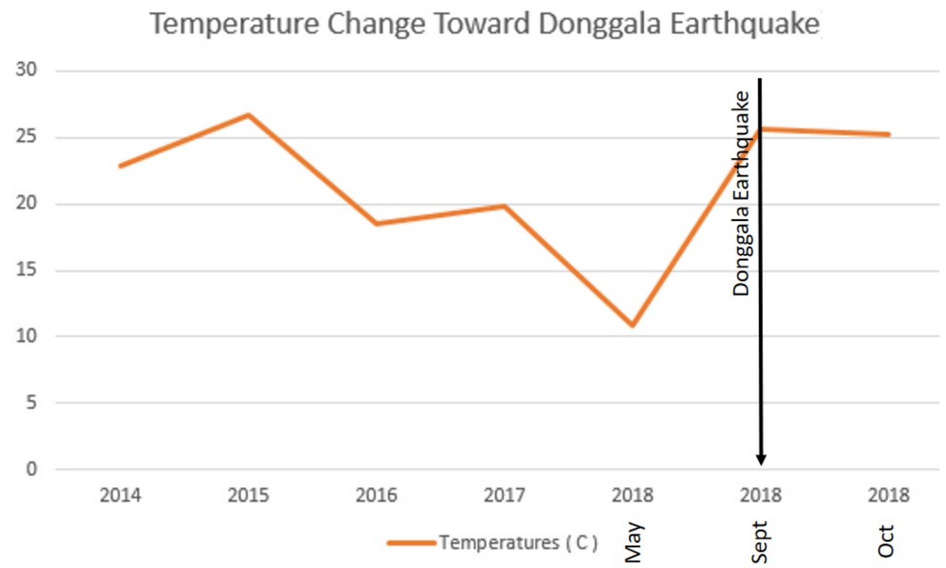

Figure 3. The LST Change Trend Before and After Main Shock Area.
(Source: Data processing)

4. CONCLUSIONS

The results of the study indicate that the areas with higher LST values are coincident with the areas of earthquake epicentrum point on this study area. LST map revealed the relationship of earthquake epicentrum with higher LST than any surrounding area prior to the earthquake event. The LST increasing from 10,82 ^{O}C in 2nd May 2018 to 25,7 ^{O}C in 23rd September 2018 (5 days before earthquake in Donggala). The study also find out that the LST would decrease after the earthquake evidence. Even though, the utilization of thermal infrared for forecasting the earthquake evidence still need further exploration in Indonesia.

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