Analyses of Landsat 8 Imageries for Preliminary Assessment to Determine Geothermal Potential Area under Torrid Zones

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ABSTRACT

There are many difficulties to create details geological map in an active volcano. The main difficulty comes from hard terrain condition to be reached which is related to the higher cost of field activity. To solve this problem, Landsat 8 imageries as an optical sensor were used in this study. The objective of this study focussed on recognizing geology of the area that will be used for geothermal exploration. The methodology in this study is analyses and interpretation of Landsat 8 image, and also applied the remote sensing technique under torrid zones.

Mt. Lamongan was chosen as study site, which is a young volcano from Mt. Tarub that located in the east. The results showed the geomorphology delineation of Mt. Lamongan indicates geological fault in NW-SE direction and there are many fractures beneath the surface, which is related with geothermal reservoir. High temperature zone in TIR (*Thermal Infrared Radiometer*) band located in the northern part of the area is associated with thermal activities, caused by existence of manifestations. The manifestations of the geothermal in the Mt. Lamongan is located in the surface near the fault system. Based on the analysis of the geomorphology and brightness temperature, Mt. Lamongan is an area that has geothermal potential. It was detected by using Landsat 8 imageries analyses. This study can be used for future development by geological, geophysics and geochemistry study to delineate area of the subsurface reservoir.

1. INTRODUCTION

Geological map generally provides of earth surface information about lithology, geomorphology, and geological structure controlled the area. The map is usually made by the geologist in a geological field activity. However, some areas are difficult to be reached mostly in the volcanic terrain. Dangerous gases like carbon dioxide (CO_2), hydrogen sulfide (H_2S), from the crater sometimes inhibits the geologist to map the feature of geology distribution in the field study. In this paper, we applied the remote sensing techniques to solve the problem.

In this study, we used Landsat 8 as an optical sensor, which part of the Landsat Data Continuity Mission was successfully launched on February 11, 2013 from Space Launch Complex-3, Vandenberg Air Force Base in California. This satellite has two sensors : OLI (*Operational Land Imager*) which have nine bands and TIRS (*Thermal Infrared Sensor*) which have two bands.

The aim of this study is to recognizing geological features of the area such as geomorphology and brightness temperature using Landsat 8 imageries. The processing of Landsat 8 remote sensing data set can be used as a powerful tool for geological mapping, including large area. However, it is not effective to acquire vegetation covers because of time consuming, date lagged and often too expensive. Some enormous efforts have been made by researchers and application specialists to delineate vegetation cover from local scale to global scale by applying remote sensing imageries using NDVI (*Normal Differences Vegetation Index*). The principle of applying NDVI in vegetation mapping is that vegetation is highly reflective in the near infrared and highly absorptive in the visible red. Therefore, NDVI is a good indicator to reflect periodically dynamic changes of vegetation groups (Geerken et al. 2005).

Mt. Lamongan was chosen as study site (Fig. 1). This volcano is a young volcano from Mt. Tarub that located in the east. The growth of Mt. Lamongan begins with Mt. Tarub fault in NW-SE direction. This fault inflict west part of the Mt. Tarub collapse, afterward the Mt. Lamongan grows.

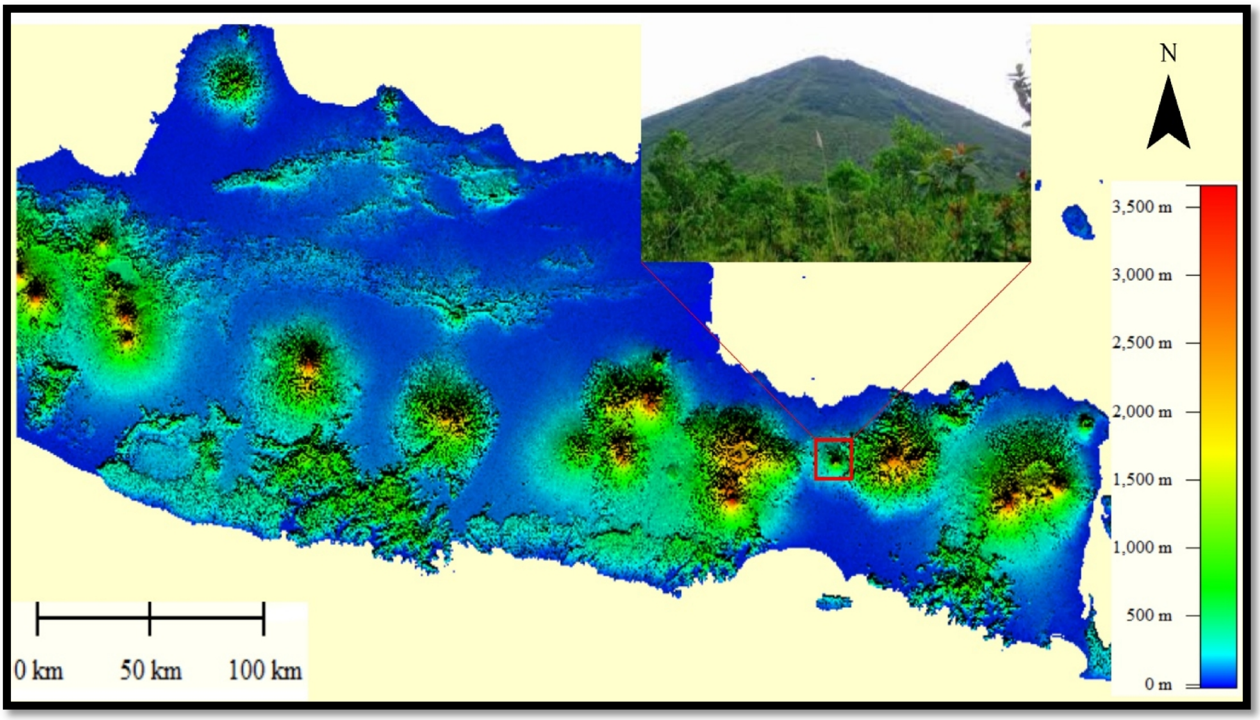

Figure 1: Digital Elevation Model (DEM) of East Java, Indonesia. Study site location shown with red square.

Among many active volcanoes spreading out in East Java, Mt. Lamongan is an interesting volcano. Mt. Lamongan has sixty four spot of parasite center eruption consists of thirty seven volcanic cone and twenty seven "maar" (Matahelumual, 1990).

This area also has surface manifestations, such as hot springs, due to the volcanic activities and some lake tourism. Such field situations will make this topic interesting to be investigated. Moreover, activities of this volcano have been monitoring for hazard mitigation due to existence of a city in the western part of the volcano.

2. DATA SELECTION AND METHODOLOGY

2.1 Data Selection

Landsat 8 is a North American Earth observation satellite in California and will join Landsat 7 satellite in orbit. Landsat 8 satellite has two main sensors: OLI and TIRS, meanwhile Landsat 7 has one main sensor : ETM+ (*Enhanced Thematic Mapper Plus*). The comparison of Landsat 7 and 8 shown in Fig. 2.

L7 ETM+			L8 OLI/TIRS		
Spectral Band	Resolution (m)	Wavelenght (µm)	Spectral Band	Resolution (m)	Wavelenght (µm)
			Band 1 - Coastal/Aerosol	30	0.433 - 0.453
Band 1 - Blue	30	0.450 - 0.515	Band 2 - Blue	30	0.450 - 0.515
Band 2 - Green	30	0.525 - 0.605	Band 3 - Green	30	0.525 - 0.600
Band 3 - Red	30	0.630 - 0.690	Band 4 - Red	30	0.630 - 0.680
Band 4 - NIR	30	0.775 - 0.900	Band 5 - NIR	30	0.845 - 0.885
Band 5 - SWIR 1	30	1.550 - 1.750	Band 6 - SWIR 1	30	1.560 - 1.660
Band 6 - TIR	60	10.00 - 12.50	Band 10 - TIR 1	100	10.30 - 11.30
			Band 11 - TIR 2	100	11.50 - 12.50
Band 7 - SWIR 2	30	2.090 - 2.350	Band 7 - SWIR 2	30	2.100 - 2.300
Band 8 - Pan	15	0.520 - 0.900	Band 8 - Pan	15	0.500 - 0.680
			Band 9 - Cirrus	30	1.360 - 1.390

Figure 2: Comparison of Landsat 7 and 8 imageries in each band (*Source : NASA "Landsat Data Continuity Mission Brochure"*).

The function of the sensor is to record the object on the earth surface which used wavelength ranged from the visible near infrared to thermal infrared. In this study, we used Landsat 8 data level-1T consisting of eleven bands which are divided into six types : Coastal Band, VNIR (*Visible Near Infrared Radiometer),* SWIR (*Short Wavelength Infrared Radiometer*), Panchromatic, Cirrus Band, and TIR (*Thermal Infrared Radiometer*). We focused on VNIR sensor to measure NDVI value, SWIR sensor to detect geomorphology, and TIR to measure brightness temperature of the area. Time selection of Landsat 8 data acquired on September 01, 2014 with clouds coverage less than 5%, makes the target area shown clearly.

2.2 Methodology

The main target of the Landsat 8 processing is to detect geomorphology, geological structure and brightness temperature. Each unit feature was characterized based on different tone, texture and structure on the images. Work flow of methodology is shown in Fig. 3.

The first step is image calibration which is divided into two types: geometric correction and atmospheric correction. The geometric correction is a procedure where the content of a map will be assigned a spatial coordinate system. This correction used to remove distortions, convert coordinate system, and to identify the location of each pixels on the Earth. To obtain good accuracy of this correction, GCP (*Ground Control Point*) must be distributed equally in the image (accuracy can be 1 pixel).

The atmospheric correction was applied to remove gases and small particles effect of the atmosphere in the imageries. This correction is very useful to get good results (Chander et al. 2007). In order to removing atmospheric effects, we have to convert temperature toward absolute temperature value (Barsi, et al. 2003). Thus, this correction is an important step to be always performed. After this correction, we can got a good image quality which was ready to be interpreted.

There are three steps to conduct atmospheric correction (USGS, 2013):

1. DN (*Digital Number*) to TOA (*Top of Atmosphere*) Radiance

The equation to convert DN to TOA Radiance is shown below (Barsi et al. 2003):

$$L_{\lambda}=\left(\frac{L_{max,\ \lambda}-L_{min,\ \lambda}}{Q_{calmax}-Q_{calmin}}\right)\left(DN\text{-}Q_{calmin}\right)+L_{min,\lambda} \quad [1]$$

where L_{λ} is sensor's TOA radiance (W/m^2-ster-μm), L_{max} is TOA radiance scaled to Q_{calmax} , L_{min} is TOA radiance scaled to Q_{calmin} , Q_{calmax} / Q_{calmin} is maximum/minimum pixel value.

2. TOA Radiance to Brightness Temperature (Kelvin)

Temperature sensor assumed that Earth's surface is a black body, involve sensor calibrate constant. Convertion equation from spectral radiance sensor to temperature (°K), is shown below (Chander et al. 2009):

$$T=\frac{K_2}{ln\left(\frac{K_1}{L_T}+1\right)} \quad [2]$$

where K_1; K_2 is constant (666.09 ; 1282.71 (W/m^2-ster-μm)), L_T is sensor's spectral radiance (W/m^2-ster-μm).

3. Brightness Temperature in Kelvin to Celcius

Converting brightness temperature in Kelvin to Celcius, is shown below:

$$T\ (^{o}C) = T\ (^{o}K) - 272.15 \quad [3]$$

The next step after image calibration is the image processing. This process included image enhancement, filtering and classification. The purpose is to delineate features of the object recorded at surface provided by the Landsat 8 imageries.

After image processing, the step was continued with image interpretation. In this step, all the information from the image processing including geological structure, geomorphology, and brightness temperature, were interpreted visually based on different tone, color, texture, and structure on the images.

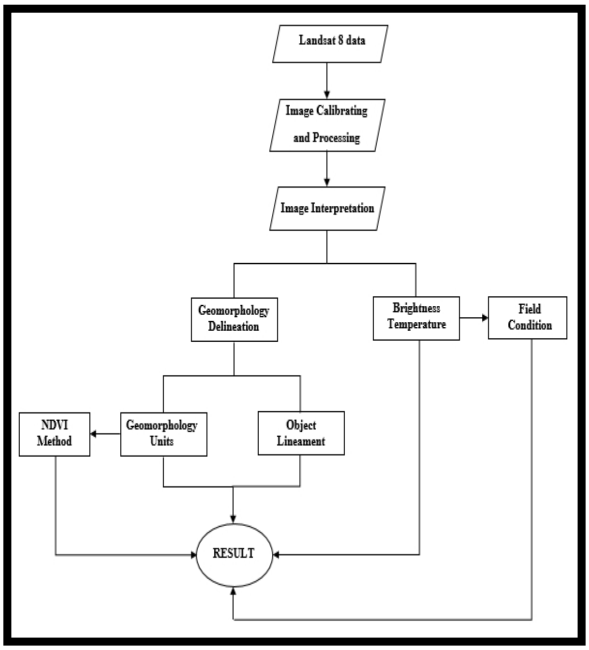

Figure 3: Flow chart of methodology.

3. GEOMORPHOLOGY AND BRIGHTNESS TEMPERATURE ANALYSES

3.1 Geomorphology Delineation

The first step in interpretating the Landsat 8 imageries is to delineate geological features, such as geomorphology units and object lineaments. These units are defined by similar shape, structure, or texture based on Landsat 8 imageries with composite band 5-6-7. This map also support the object lineament, especially in the area of study.

There are two geomorphology units in Mt. Lamongan, called as Lamongan products and Outer Lamongan product. Lamongan product is a geomorphology unit where the materials originate from Mt. Lamongan. This unit characterized by flow impression on Landsat 8 imageries and differentiated by Outer Lamongan product (Fig. 4). The materials of Outer Lamongan product are composed by others volcano surrounding the area of study, especially from Mt. Tarub and Mt. Argapuro.

The differences between Lamongan product and Outer Lamongan product also detected using NDVI method (Fig. 5). The Lamongan product is characterized by low NDVI value by rare vegetation. Values is approximate from -0.002 until 0.341. However, the NDVI value of Outer Lamongan product is higher than Lamongan product because of existence of dense vegetation, such as forests, bare soil, lawn, or scrub.

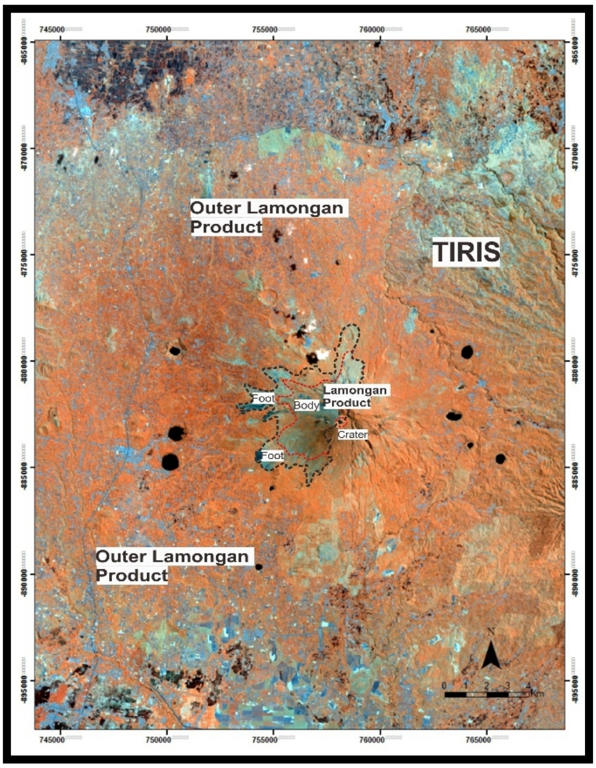

Figure 4: Image interpretation shows the differences of volcanic product distribution

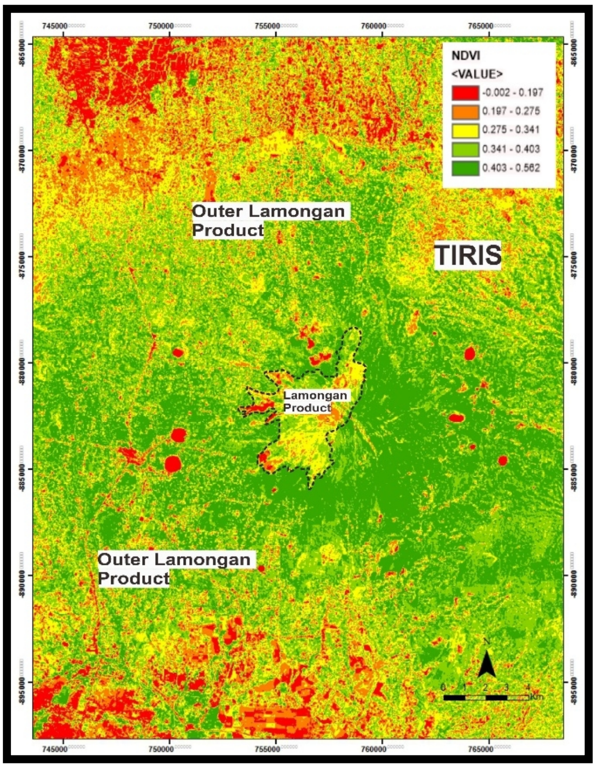

Figure 5: NDVI Value of Mt. Lamongan represents vegetation land cover at study area.

The Lamongan product located in the north and west flank were divided into three geomorphology units, called as the crater, the body, and the foot of the volcano. The crater showed an opening feature on the top of the volcano, the body of the volcano is characterized by spreading structure, and the foot of the volcano is located in the lowest slope (Fig. 4).

This image interpretation from Fig. 4 also conducted by looking the trend of object lineament. From the Fig. 6, showed that the direction of geological fault are in NW-SE direction, marked by long lineament (black line). There are two geological faults, which is on the body of Mt. Lamongan and Tiris area.

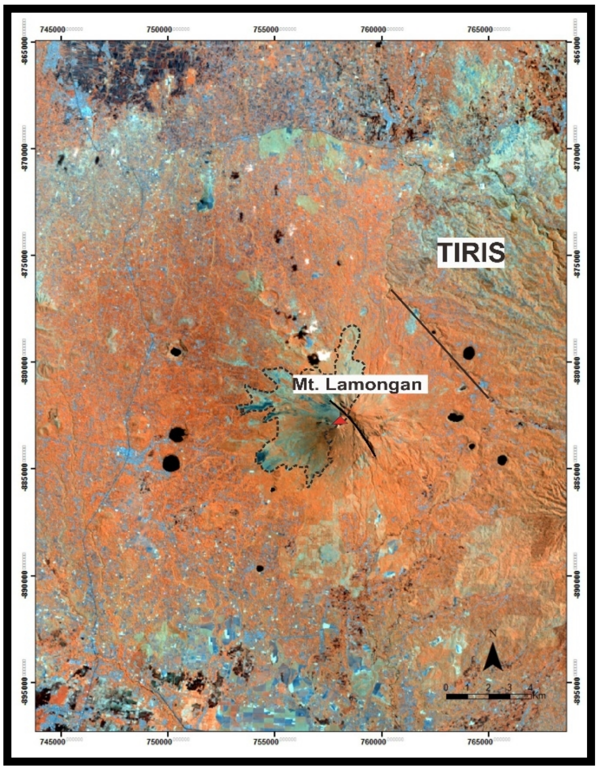

Figure 6: Structure lineament identification on image interpretation of Mt. Lamongan, Tiris and surrounded area.

3.2 Brightness Temperature

Landsat 8 imageries that using for mapping the brightness temperature is band 10 (10.30-11.30 μm), from TIRS. Assuming that the Earth's surface is a black body with emissivity 1, the top of emission of the Earth that have average of brightness temperature for about 300^{o}K with wavelength of 10 μm.

Atmospheric correction and temperature conversion from TOA radiance to brightness temperature, as shown in the Fig. 7 for Mt. Lamongan (area of study marked with black dotted) and surrounded area. Brightness temperature value that acquired ranged from 10^{o}C – 40^{o}C. Low temperature (until minus) typically associated with cloud temperature, meanwhile high temperature typically associated with volcanic phenomena. Temperature cluster with interval 4^{o}C from temperature 14^{o}C – 35^{o}C conducted to be interpretated easily.

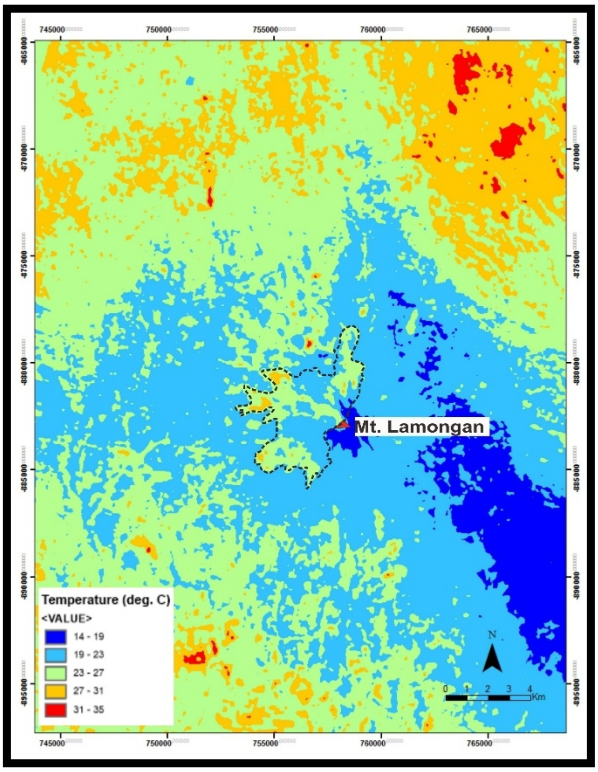

Figure 7: Brightness temperature of Mt. Lamongan, and surrounded area.

In the northern and southwest part of the area, the brightness temperature are high with approximate temperature of 23°C – 35°C, shown by green, orange, and red color (Fig. 7) . Most likely, can be interpretated that this area is associated with thermal activities, such as geothermal manifestation. In the western and southeast part of the area, the brightness temperature are low with approximate temperature of 14°C – 23°C (shown by blue color in Fig. 7), that associated with cloud, lake, or river.

4. RESULT AND DISCUSSION

4.1 Geomorphology Delineation

Generating a geological map manually at field usually spends a lot time and works. It was of course depending on coverage area and condition. In volcanic area, high topography, dense vegetation without a good route to be reached, makes geologist facing problem to map the area.

Analysis for Landsat 8 band 5-6-7 is useful to distinguish morphology units. Morphology of Mt. Lamongan is different with other products surrounding the volcano. The Lamongan product is characterized by flow impression and distinguished by Outer Lamongan product.

In addition, main analyses is to marking areas which are affected by a geological fault. Uniformity of the direction of an object will show a pattern of a geological fault in the area of study. In the Mt. Lamongan, Tiris and surrounded area, two geological faults is characterized by structure lineament identification in NW-SE direction : on the body of Mt. Lamongan and Tiris area (Fig. 6).

On the weaken zones beneath the Earth's surface, there are many apriori fracture that indicates a geothermal reservoir. Fluid that keep heated by the heat source will flow and gather in the geothermal reservoir. The fracture in this area indicated by existence of geological fault that obtained from structure lineament identification (Fig. 6). Geological fault can be used for the indicator as the prospect area that has geothermal potential. Thus, Tiris area in the northern part is an area that has geothermal potential because it is associated with geological fault.

4.2 Brightness Temperature

Image interpretation can help us to obtain geological fault location. In the fault area, existence of manifestation is very big. Surely, this manifestation distinguish by temperature radiation that higher than surrounded area.

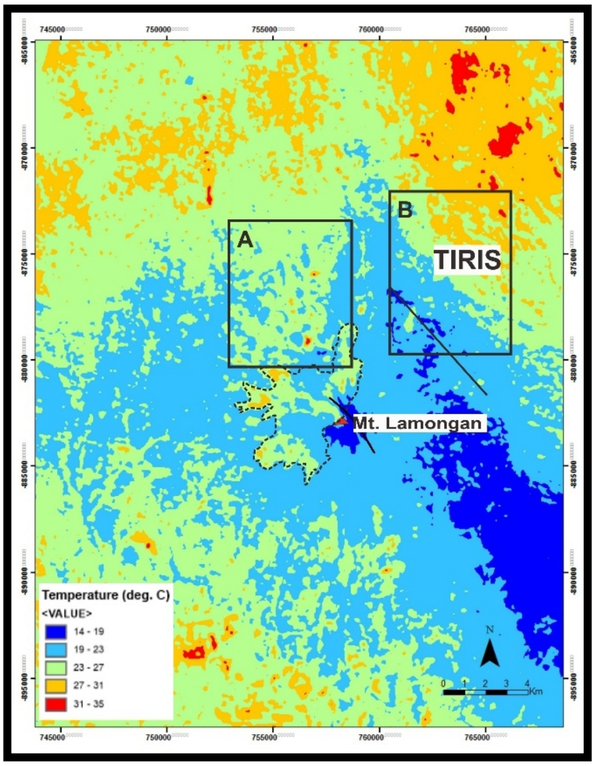

Figure 8: Brightness temperature of Mt. Lamongan, Tiris and surrounded area : Area A and B is an area that associated with geothermal potential.

From the Fig. 6, geological fault marked with black straight line is related with high temperature zone in area B (Fig. 8). Can be seen that area A and Tiris area (Area B) have high temperature with ranged 23°C – 35°C. High temperature zone that scaterred in the northern part of the study area is associated with thermal activites, caused by existence of surface manifestation.

This result according with the field condition that surface manifestation occurred in the Tiris area with temperature 42°C, and scattered in the northern part of the area (Bronto et al. 1986). Present, this manifestation is used for one of the local tourism in the Tiris area.

5. CONLUSIONS

Analysis for Landsat 8 band 5-6-7 is useful to distinguish morphology units and band 10 to distinguish brightness temperature. The Lamongan product is characterized by flow impression and distinguished by Outer Lamongan product. The result of the study showed that the geomorphology of Mt. Lamongan indicates geological fault in NW-SE direction and many fractures beneath the surface related with geothermal reservoir.

High temperature zone in the northern part of the area also related with geological fault (Fig. 8) because it is associated with existence of surface manifestation (Bronto et al. 1986). Surface manifestation occurred to the surface through the fault path. This fault showed that Tiris area has geothermal potential.

To make clearer result and also for reference while interpreting the Landsat 8 imageries, we need to conduct geological, geophysics and geochemistry study to delineate potential area, especially near the fault area and toward Mt. Lamongan area. The analysis will be valid after applied atmospheric correction of the Landsat 8 imageries is performed and if the coverage of vegetation is rare.

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