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PRELIMINARY INTERPRETATION FOR GEOTHERMAL POTENTIAL AREA USING DEM AND LANDSAT OLI 8 IN MOUNT ENDUT

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ABSTRACT

Regard to the increasing need for fossil energy in Indonesia, it is necessary to explore alternative energy. For example is geothermal energy, which is known as a sustainable and eco-friendly energy source. Indonesia is one of the countries with the most substantial geothermal potential reaching 23.9 GW. Therefore, this study using the remote sensing method to predict potential areas for geothermal systems in the Mount Endut, Lebak, Banten. The research using Landsat 8 OLI for analysis Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST), along with DEM imagery is used for Fault Fracture Density (FFD) analysis. The results of Land Surface Temperature (LST) analysis showed the highest value in the northern and middle part of the research area with a value of 33.7°C. This is related to the results of the NDVI analysis, which areas has lower values in the northern and middle areas with values about 0.36 - 0.06. The lineament mostly has a northwest-southeast direction, with the highest value of the lineament density is 2.69 km / km^2, mostly located in the middle part of the research area that can be related to the weakest zone as a geothermal path to the surface. Based on the results, it shows the relationship between the LST is the opposite of the NDVI value. Thus, it can be concluded that the area which has geothermal potential is located from western to the middle of the research area, which is correlated with the presence of manifestation regarding to hot springs.

Keywords: *Geothermal, Remote Sensing, Landsat OLI 8, DEM Imagery, Mount Endut.*

ABSTRAK

Terkait kebutuhan energi fosil yang semakin meningkat, perlu dilakukan eksplorasi energi alternatif. Contohnya yaitu energi panas bumi yang selama ini dikenal sebagai sumber energi berkelanjutan dan ramah lingkungan. Indonesia memiliki potensi panas bumi mencapai 23.9 GigaWatt. Oleh karena itu, pengembangan teknik eksplorasi panas bumi diperlukan, salah satunya yaitu dengan menggunakan metode penginderaan jauh. Penelitian ini dilakukan untuk memprediksi potensi wilayah panas bumi di kawasan Gunung Endut, Kecamatan Lebak, Provinsi Banten. Data Landsat 8 Operational Land Imager (OLI) digunakan untuk menganalisis Normalized Difference Vegetation Index (NDVI) dan Land Surface Temperature (LST), serta citra DEM yang digunakan untuk analisis Fault Fracture Density (FFD). Hasil analisis LST menunjukkan nilai tertinggi berada pada bagian utara dan tengah dari daerah penelitian dengan nilai 33,7°C. Hal tersebut berkaitan dengan hasil analisis NDVI, dimana wilayah yang memiliki nilai lebih rendah berada pada bagian utara dan tengah daerah penelitian dengan nilai sekitar 0,36 - 0,06. Dominansi lineament menunjukkan arah barat laut – tenggara, dengan nilai densitas kelurusan paling tinggi adalah 2,69 km/km2 yang terletak di bagian tengah daerah penelitian, hal tersebut dapat mengindikasikan zona paling lemah sebagai jalur keluarnya panas bumi ke permukaan. Hasil analisis menunjukkan bahwa hubungan antara nilai LST berbanding terbalik dengan nilai NDVI. Sehingga dapat disimpulkan bahwa area yang memiliki potensi panas bumi berada di bagian barat hingga tengah dari daerah penelitian, sesuai dengan keberadaan manifestasi panas bumi yang saat ini telah ditemukan, berupa mata air panas.

Kata kunci: Panas bumi, Penginderaan Jauh, Landsat OLI 8, Citra DEM, Gunung Endut.

INTRODUCTION

Fossil energy has become a primary need to increase the national economy. In essence, the more demand, the more limited availability of the resources so that it can cause an imbalance between the level of consumption and production. As non-renewable energy, fossil energy is not sustainable. Therefore, other energy resources are needed as alternative energy.

In a large area and contains a diversity of alternative energy, Indonesia has a great opportunity to fulfill national energy demand in the future. One of the potential renewable energy resources is geothermal energy. Geothermal energy is known as a sustainable and eco-friendly energy resource that can be used as a source of electrical energy. According to the latest records of Badan Geologi and Direktorat Panas Bumi, Indonesia is one of the countries with the most substantial geothermal potential reaching 23.9 GW. However, this potential has only been utilized around 8.9% or equivalent to 2,130.6 MW. Geothermal energy is defined as heat from earth that continuously flows outward. Geothermal system requires heat, permeability, and water (Leslie Blodgett, et al, 2009). Most of the geothermal energy is the result of extraction from the hydrothermal system associated with a volcanic system. Located in the "ring of fire" region, strategically places Indonesia as the richest country with geothermal energy using hydrothermal systems scattered along volcanic arcs.

Mount Endut is one of the highest mountains in Banten Province with an altitude reach 1,207 meters above sea level, has an average rainfall of 4000 - 6000 mm / year. This research was carried out at coordinates 106°15'27.2"E, 6°33'58.2"S - 106°22'29.3" E, 6°41'2.6" S which has an altitude interval about 180 - 1,262 meters above sea level. In the study area, several locations of manifestations were found refer to hot springs with an average surface temperature of 64.875 °C at an elevation around 200-500 meters above sea level located at coordinates 106.2992 E, -6.6106 S; 106.2764 E, -6,6146 S; and 106.2994 E, -6.6105 S (Figure 1).

Remote sensing is a method for access information about objects, areas, and phenomena by data analysis obtained from tools that do not directly contact the object of research (Lillesand dan Keifer, 1979). Therefore, this method is considered more effective, efficient, and requires low cost. This information is gained from electromagnetic radiation that has been reflected or radiated from the earth's surface (Lindgren, 1985). The information is then processed and analyzed to obtain results in accordance with the purpose. Remote sensing aims is to find for geothermal potential before coming to the field. The result of this Landsat image processing is the distribution of hot spots that can be used as a reference in observing geothermal manifestations.

Application Remote sensing in geothermal exploration is still rarely encountered. By analyzing the condition of vegetation and the temperature level, this study can be used to map the distribution of geothermal potential in the study area. The research using Landsat 8 OLI to analyze Normalized Difference Vegetation Index (NDVI), which aims to know the earth's surface type. This remote sensing uses Landsat OLI 8 satellite images for studio Surface Temperature (LST) as a source of geothermal distribution, and DEM satellite images for Fault Fracture Density (FFD) studies as locating highly fractured areas, to find out the weak zones that can act as paths for thermal fluid to flow from the reservoir at depth to the shallower level.

These research aims are to identify the vegetation density index and surface temperature distribution in the geothermal area of Mount Endut and it's relation to geothermal manifestations, also to know the location of the manifestation by describing the lineament density analysis based on the FFD method. Furthermore, after all of the remote sensing method we use, we can find out the geothermal prospect zones in the research area.

REGIONAL GEOLOGY

Geology of the resarch area surrounding Mount Endut, where most of it's lithologies consists of quaternary volcanic deposits that break trough tertiary sedimentary bedrock (Kusnadi, 2006). Geothermal manifestations around the study area are the Cikawah and Handeuleum hot springs.

Based on the previous researcher (Kusnadi,2006), The geology of the investigation area is dominated by Quaternary volcanic rocks of Mount Endut products that break through Tertiary sedimentary bedrock. In the southern part of the investigation area, many intrusive rock products are thought to have formed before Mount Endut volcanism.

The stratigraphy of the Mount Endut area is stacked based on the relative relationship between each rock unit. The name based on the eruption center, mechanism and rock formation genes. The results of field investigations (Figure 2) show rocks Mount Endut are divided into 16 units. Initially at the age of miocene formed Sedimentary Unit Badui (Tmd), then Sedimentary Unit Bojongmanik (Tmb). Furthermore, formed Andesitic Intrusive (Ta), and then Volcanic Rock PraEndut (Tlpe) whose source from Mount Pra-Endut eruption. At the age of pliocene formed Breccia lava Mount Kendeng (Tbr), and then Lava Mount Pilangranal (Tlr) whose source from Mount Pilangranal eruption. Furthermore, formed Diorit (Td), and Granodiorit (Tgr). At the age of plistocene formed Breccia Lava Mount Pilar (Qbp), and then Lava Mount Pilar (Qlp) whose source from Mount Pilar eruption. Furthermore, formed Lava Mount Endut-1 (Qle1), then Piroclastic Flow Mount Endut (Qae), then Lava Mount Endut-2 (Qle2), then Breccia lava Mount Endut (Qbe), then Lava Mount Endut-3 (Qle3) whose source from Mount Endut eruption. At the age of Holocene formed Aluvium (Qal).

According to Kusnadi et al. (2006), in their research, Based on the image analysis, the geological structure that occurs in the area of Mount Endut consists of: Normal faults that have a northwest-southeast direction are indicated by the appearance of intrusive and volcanic regions of Mount Endut. Horizontal fault and reactivation to normal, trending northeastsouthwest which cuts formation to the basement and causes the appearance of manifestations in the form of a row of Cikawah hot spring and structures in the crater of the Mount Endut. Horizontal fault and reactivation of the normal alteration of silicified brecciated andesite to the northeast-southwest direction and cause sealing to the manifestation of Cikawah hot springs.

The existence of alignment direction is almost north-south which intersects the previously formed structure. The horizontal fault is trending northwest-southeast which cuts through rocks and previously formed structures. Handeleum hot spring manifestation allegedly arises because of this structure.

METHODS

Satellite data

In conducting geothermal potential research, there are several methods that can be applied, one of which is the remote sensing that we use for the research of geothermal potential in the Mount Endut area. Research using this method in geothermal exploration is still rarely found. The research use Landsat 8 Operational Land Imaginer (OLI) that included in the secondary data obtained by downloading on the USGS earth earthexplorer page (Azhari, 2016). Landsat analysis is commonly used to determine conditions on the surface of the earth by looking at the character of reflectance and adsorption of electromagnetic waves from objects that are on the surface of the earth (Sabins, 1999). Landsat 8 OLI is use to analyze Normalized Difference Vegetation Index (NDVI) dan Land Surface Temperature (LST). Normalized Difference Vegetation Index (NDVI) which is aims to knows the earths surface type. Land Surface Temperature (LST) as a source of geothermal distribution, and DEM satellite images for Fault Fracture Density (FFD) studies as locating highly fractured areas, to find out the weak zones that can act as paths for thermal fluid to flow from the reservoir at depth to the shallower level.

Normalized Difference Vegetation Index (NDVI)

NDVI works by counting reflections from the light absorbed and reflected across bands, so we can find out which parts have a good or bad reflection of vegetation based on the infrared spectrum approach. The value in NDVI has an average index range from -1 to 1, with a value of -1 representing the minimum or absence of plants, and a value of 1 representing a maximum value. To find out the land cover of the study area by using bands 4 and 5 from Landsat OLI 8 data. The formula is :

$$NDVI = \frac{RNIR - RR}{RNIR + RR} \quad (1)$$

Where,

NDVI stand for Normalized Difference Vegetation Index;

RR is Red Reflectance (Band 4);

$RNIR$ is Near Infrared Reflectance (Band 5)

Land Surface Temperature (LST)

LST can be calculated using satellite sensors, in the form of infrared or micro wavelength. LST can detect the presence of vegetation and soil moisture so that it can be used to detect land changes. The temperature calculated by LST is the temperature at the earth's surface, depending on the temperature distribution and the emissivity of the spectral channel of measurement (Becker and Li 1995). The data used to calculate LST are using Landsat 8 OLI Band 10 as a thermal band, and Bands 4 and 5 to calculate NDVI. The inversion of the Planck function algorithm is used to find the LST value. The first step is to calibrate the band value which is still a digital number (DN) to become spectral radians (TOA radians) Top of Atmosphere Correction (ToA) or radiometric correction function is to increase the pixel value by considering atmospheric interference factors so that information can be read and interpreted clearly.

$$TOA\ (L) = M_L \times Q\text{cal} + A\text{L} \quad (2)$$

Where:

TOA (L) = spectral radiance (W/m^2)

M_L = Band-specific multiplicative rescaling factor from the metadata (0.00033420) Q_{cal} = Pixel value in digital number corresponds to band 10.

A_L = Band-specific additive rescaling factor from the metadata (0.1)

After correcting the atmosphere, then determining the brightness temperature value (BT). This calibration is used for converting the thermal bands of TIR to Brightness temperature as a microwave radiation radience that traveling upward from the earth's surface by using equation below.

$$BT = \left(\frac{K2}{\ln\left(\frac{K1}{L}\right) + 1}\right) - 272.15 \quad (3)$$

Where:
L = TOA
BT = Brightness Temperature (K)
K1 = Spectral radian calibration constant (7
K2 = Absolute temperature calibration constant in kelvin (1321.0789)

Correction of surface temperature to emissivity value is used to reduce errors in LST calculations. When the pixel NDVI value is composed of a mixture of vacant land and high vegetation, so the emissivity value is obtained through the proportion of vegetation (Pv) by this following vegetation equation.

$$PV = \left(\frac{(NDVI - NDVImin)}{(NDVImax - NDVImin)}\right)2 \quad (4)$$

Surface emissivity is the ability of an object to radiate their energy. Earth's surface on land has variations in emissivity, including variations in vegetation cover, vegetation composition, humidity, and surface roughness structures (Fawzi and Naharil, 2013). To obtain the surface emissivity value (ε), use the equation 5.

$$\varepsilon = m \times Pv + n \quad (5)$$

Where:
ε = Land Surface Emissivity
m= Surface emissivity standard deviation constant (0.004)
n= The emissivity value of vegetation minus (0.986)

After all of the calculations, the LST value is calculated using equation 6 below.

$$LST = \frac{BT}{\left(1 + W \times \left(\frac{BT}{P}\right) \times \text{Ln}(\varepsilon)\right)} \quad 6)$$

Where:
W = wavelength of emitted radiance (11.5 μm) $P = h \times \frac{c}{s}$ = 1,438 $\times 10^{-2}$ m K
h = planck's constant = (6.626 × 10^{-34} Js) s = Boltzmann constant = (1.38 $\times 10^{-23}$ J/K) c = Velocity of light = (2.998 $\times 10^{-8}$ m/s)

Lineament Orientation

This study uses data digital elevation map Nasional (DEMNAS imagery) which has been converted into a hillshade map using ArcGis software using the hillshade tool in the ArcGis toolbox. Next, the hillshade map is processed using Geomatica software to extract the lineament automatically by utilizing the Librarian Algorithm - Lineament Extraction function to produce a lineament map from the study area which is the lineament was based the morphology of the study area, such as valleys or mount ridges. Then the results of the lineament extraction data are processed using Rockworks software to produce an output rosette diagram by calculating the length of the lines in certain direction divided by the total lineament in the research area for determining the direction of the alignment of the area.

Lineament Density

Calculation of line density is carried out with the aim to find out the concentration and distribution patterns of morphological lineaments (Kim, 2003 in, Trisdinadiansyah et al., 2017). The calculation of line density was explained by Hung et al., (2005) in Trisdinadiansyah et al., (2017) as follows:

$$Lineament\ Density\ (km/km^2) = \frac{Total\ Lineament\ Length\ (km)}{Grid\ Area\ (km^2)} \quad (7)$$

This Lineament density map are supported by ArcGis software. Lineament extraction made by Geomatica is a line data in the form of a polyline, so that the results of the lineament extraction from Geomatica must be changed to a single line using the split lineament tool in the ArcGis toolbox because density maps require single line data input to create a line map density. Then the single line extraction input data is processed using the density map tool in the ArcGis toolbox to produces a line density map output. Then the map will be analyzed and interpreted further to see areas that have dominant lineament distribution as an indication of the number of fractures that can represent weak zones as geothermal fluid pathways (Wibowo, 2010).

RESULT AND DISCUSSION

Normalized Difference Vegetation Index (NDVI)

Based on the results of NDVI data in the study area using ArcGIS, the NDVI has a minimum value of 0.06 was obtained with red and a maximum value of 0.54, which obtained with green (Figure 4). The higher the vegetation index value, the higher the vegetation density. The more the value approaches 1, the higher the vegetation density. The result from the NDVI map shows the dominance of good vegetation density. The correlation between NDVI and LST is shown in the Figure 3. The table shows that NDVI and LST are inversely related. In areas that have a low NDVI value, have a high LST value; the higher the NDVI value, the lower the LST value. That means that the less vegetation density, the higher the surface temperature, and the more vegetation density, the lower the surface temperature.

Land Surface Temperature (LST)

The distribution of soil surface temperature associated with geothermal manifestations can be done with remote sensing technology, the presence of geothermal potential in an area can be known by the emergence of geothermal manifestations such as hot springs (Faridah, 2014). In the research area, 3 hot springs can be identified. According to Zhang, 2012, the higher the surface temperature, the greater the possibility of geothermal potential areas.

Based on the analysis of the Land Surface Temperature map, Mount Endut in the study area has an LST value range from 23.07˚C - 33.73˚C. The heat source in the Mount Endut geothermal system is estimated to come from the remaining heat in the form of volcanic domes around the Cikawah and Handeuleum manifestations. Geothermal manifestation found at high temperature with a range of values from 25.92˚C - 27.10˚C (Figure 5).

Based on the analysis of the LST distribution curve histogram at the figure 6, it can be seen that the lowest temperature has a value of 23.07˚ C and the highest temperature is 33.73˚C. The dominant temperature in the study area is at a value of 26.62˚C and the surface that has a low value to medium occupies a wider area.

After being analyzed, it can be seen that the hotspots found in the study area are in areas that have high LST values and low NDVI, where there is not much vegetation.

Lineament Orientation

The lineament orientation requires DEM data to describe the morphology of the study area such as ridges and valleys. The existence of these ridges and valleys can represent the direction of tectonic deformation, and also to determine the direction of the source associated with changes in the hydrothermal process. Lineament calculations were processed using automatic extraction of 1388 data, then the data is used to make a rose diagram to analyze the direction of the lineament in research area The result of the lineament interpretation depicted by the rose diagram shows that the trend is developing in area are relatively equal, especially northwest - southeast (Figure 7). This is consistent with the main geological structure pattern in regional geology which is controlled by several fault segments that have a northwest - southeast orientation (Figure 7). The trend that develop represent the pathway for fluid migration from the subsurface to the surface.

Fault Fracture Density (FFD)

According to William (1983), topographical features on the earth's surface that represent a zone of weakness can be indicated by a lineament. The mapped lineament density will get information about the permeable zone in an area to determine the weakest zone as geothermal manifestation. Based on the calculation of density value using the Fault Fracture Density (FFD) method, Mount Endut's research area is divided into three density classes, namely low density indicated by dark green - light green color ranged from 0 - 0.89 km / km2, medium-density indicated by light green - orange ranged from 0.89 to 1.79 km / km2. The high density indicated with the orange-red color ranged from 1.79 to 2.69 km / km2 (Figure 8). Areas that have high lineament density are located in several areas particularly, in the northeast, southeast, and northwest of the study area which may have a geothermal manifestation zone. A black circle on the map marks this area. While the western part of the study has a low density, this shows that geothermal manifestations are difficult to find or far from geothermal sources.

Geothermal Potential Zone

The potential geothermal zone can be determined by overlying some data such as vegetation index value, surface temperature value, fault and fracture density (FFD), lineament orientation, and surface manifestation data found by the previous researcher.

The NDVI value has a consistent correlation with the LST value. In the west area of the map which found a manifestation in it, has a low NDVI of 0,30096272 and a high LST value of 25,92061381˚C. The lineament patterns show the primary trend of NW – SE (Figure 8). From the Fault Fracture Density method, a high-density zone with a value of 1,79 – 2,69 km/km² taken place on the northeast (NE), southern (S), and Northwest (NW) part of the research area.

The geothermal prospect area of Mount Endut is at the western of Mount Endut with an area of 25.870 Hectares, which is also found in the manifestation of hot spring. The geographically located on 106.2992 E, -6.6106 S; 106.2764 E, -6,6146 S; and 106.2994 E, -6.6105 S. And administratively located on the Lebak Regency.

CONCLUSION

In conducting research to predict the potential of the geothermal area, there are several methods that can be applied. The research methoduses remote sensing analysis based on Landsat 8 OLI. Remote sensing is one of the method that considered more effective efficient, and requires low cost. This method can be used as a reference in observing geothermal manifestation.

The result of the NDVI analysis shows a value of 0.06 - 0.54. NDVI map shows the dominance of good vegetation density. Because The high vegetation index dominance in this area. The study area has an LST value range from 23.07˚C - 33.73˚C. NDVI and LST have a correlation. In areas that have less vegetation density, then the higher the surface temperature, and the more vegetation density, the lower the surface temperature. Based on the result of LST, geothermal manifestaion found at high termperature with a range of values from 25.92˚C - 27.10˚C. The result of the lineament analysis using DEM data shows that the trend is developing in area are relatively equal and the trend that develope represent the pathway for fluid migration from the subsurface to the surface. Mount Endut's research area is divided into three density classes, namely low density indicated by dark green - light green color ranged from 0 - 0.89 km / km2, medium-density indicated by light green - orange ranged from 0.89 to 1.79 km / km2 and the high density indicated with the orange-red color ranged from 1.79 to 2.69 km / km2 (Figure 9). Areas that have high lineament density are located in several areas particularly, in the northeast, southeast, and northwest of the study area which may have a geothermal manifestation zone. A black circle on the map marks this area. While the western part of the study has a low density, this shows that geothermal manifestations are difficult to find or far from geothermal sources (Figure 9).

It can be concluded that the high prospect area of Mount Endut is at the western of Mount endut with an area of 25.870 Hectares, The geographically located on 106.2992 E, -6.6106 S; 106.2764 E, -6,6146 S; and 106.2994 E, -6.6105 S. And administratively located on the Lebak Regency. In this area also found the manifestation of hotspring.

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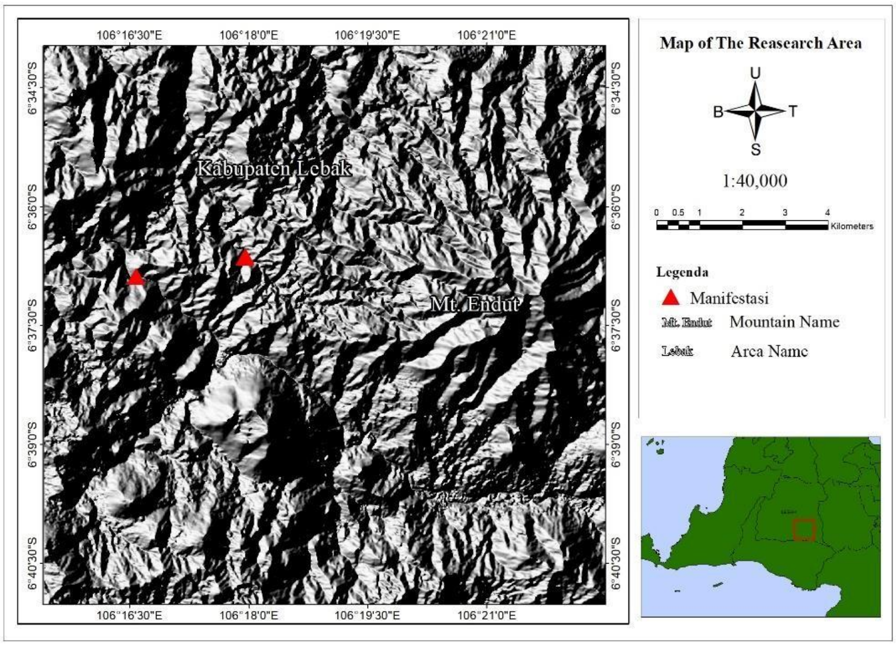

Figure 1: Research Area Based on DEM Imagery

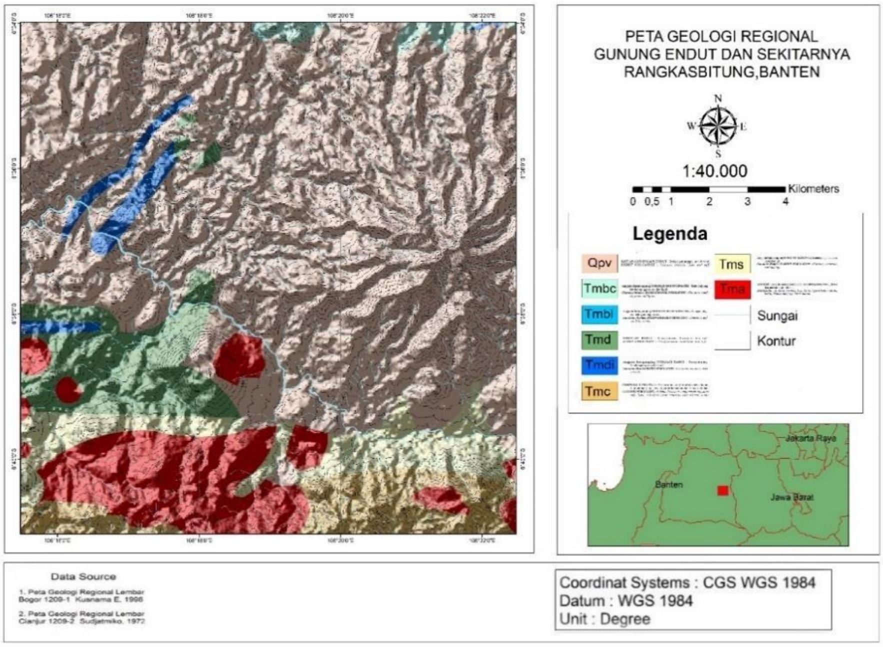

Figure 2: Regional Geological Map of Mount Endut Area.

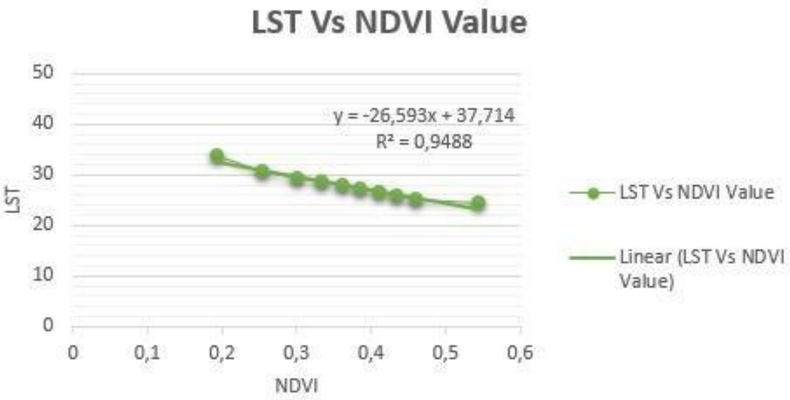

Figure 3: Correlation between land surface temperature and normalized vegetation index.

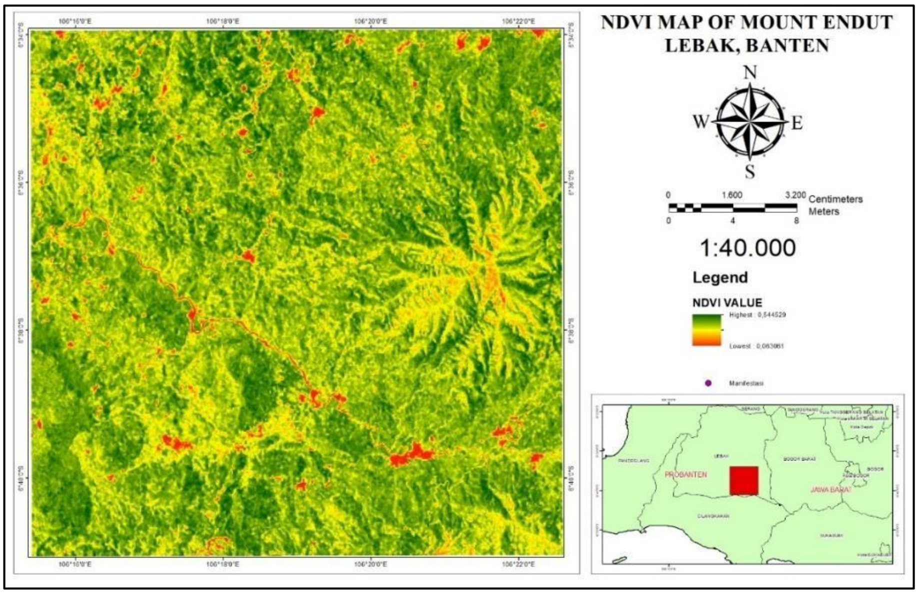

Figure 4: The Vegetation Index Distribution Map in Mount Endut. The map shows the area mostly covered by the vegetation in the almost part of the map

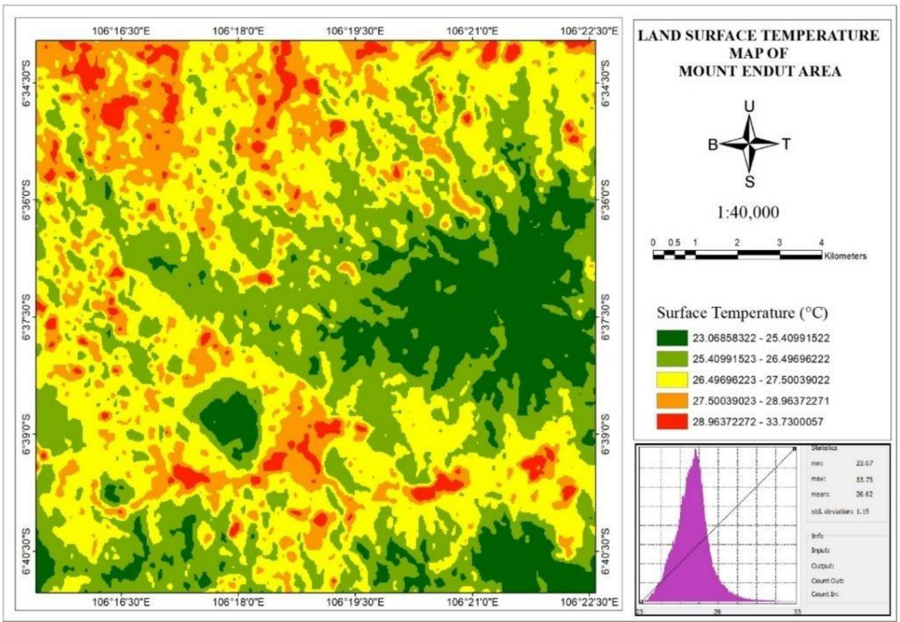

Figure 5: The Land Surface Temperature Map

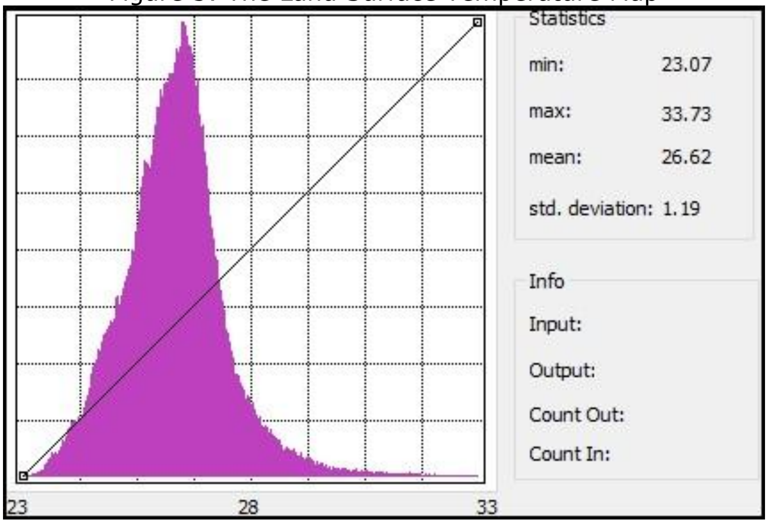

Figure 6: The Histogram of LST in Mount Endut.

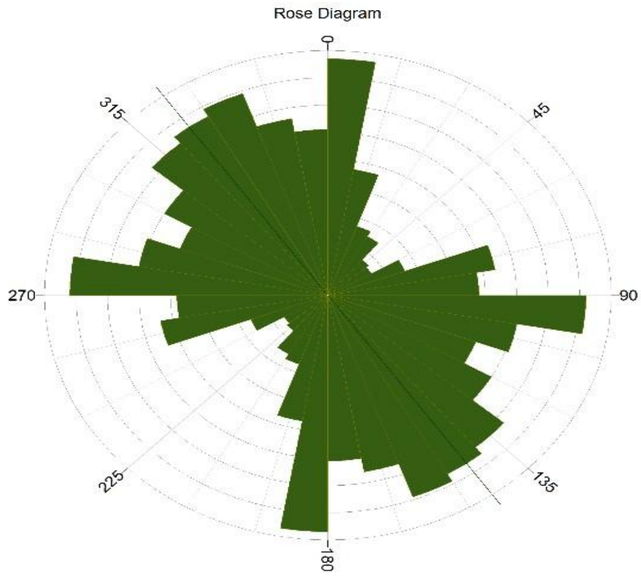

Figure 7 : The Rosette Diagram of Lineament in Mount Endut.

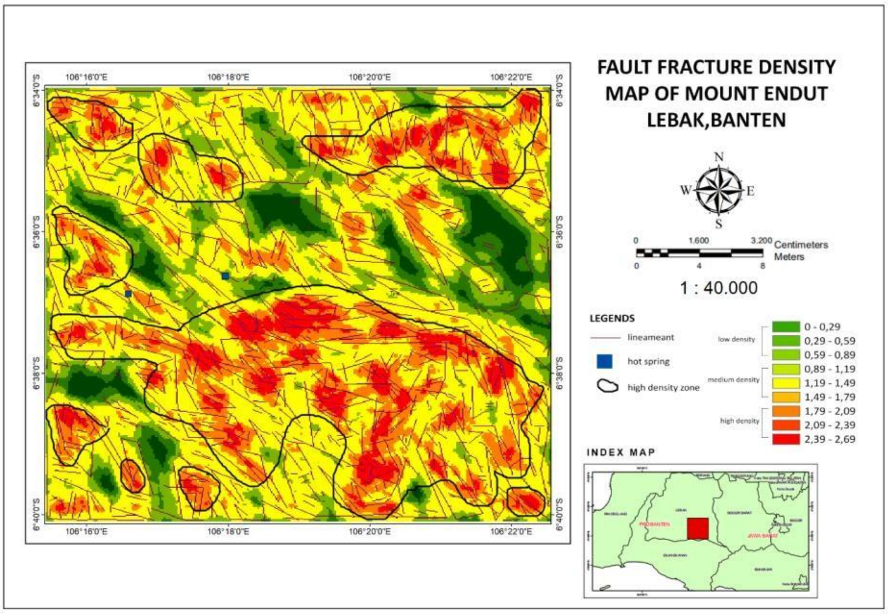

Figure 8: The Fault Fracture Density Map.

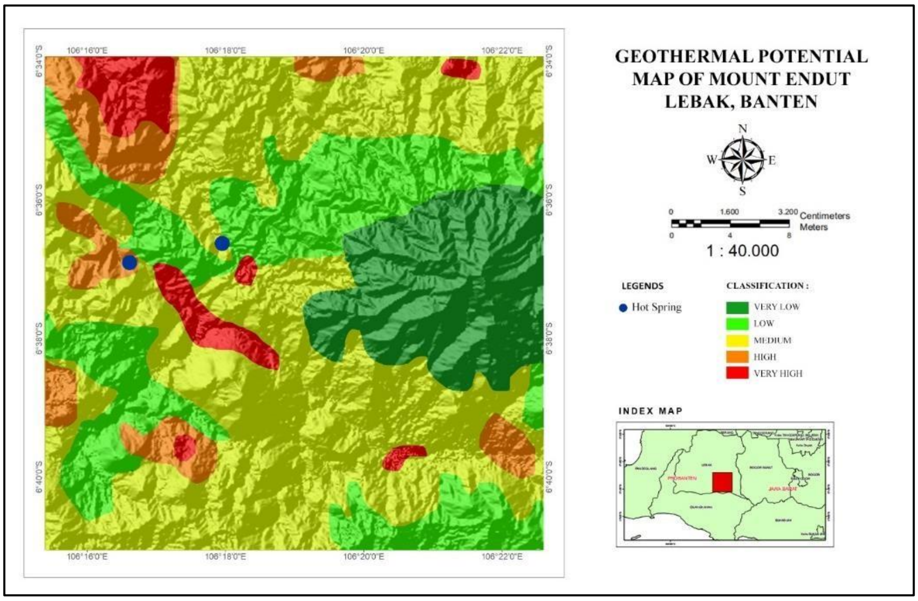

Figure 9: The Geothermal Potential Map.