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Identification of The Relationship Between LST And NDVI On Geothermal Manifestations In A Preliminary Study Of Geothermal Exploration Using Landsat 8 OLI/TIRS Imagery Data Capabilities: Case Study Of Toro, Central Sulawesi

Risma Kamila Syawalina[1] , Fina Ratihmanjari[1], Rizal Azhari Saputra[1]

[1]Department Geological Engineering, Faculty of Exploration and Production Technology, Pertamina University, Jakarta 12220, Indonesia

kamilarisma24@gmail.com

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ABSTRACT

Geothermal energy is a renewable energy resource that environmentally friendly and derived from natural processes. Based on data from the KESDM in 2020 the geothermal potential in Indonesia is 23,765.5 Mwe and 2,175.7 Mwe has been utilized or 9% of the total potential. Therefore, the potential for geothermal energy needs to be carried out through the development of geothermal exploration, one of them using remote sensing technology. Remote sensing is a technique to collect information about an object and its environment over a long distance without physical touch. Remote sensing techniques used in this research are Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) methods. This method can be an alternative to identify the presence of geothermal energy in geothermal exploration and can help to confront exploration challenges in terms of time effectiveness, economic, and accessibility to exploration locations. The research location at Toro, Central Sulawesi Province. According to KESDM data from 2017, manifestations of Toro hot springs have temperatures ranging from 25 –60°C. This study aims to identify the relationship between LST and NDVI to Toro hot springs. In conducting LST and NDVI analysis, Landsat 8 OLI/TIRS data was used to determine the distribution pattern of surface temperature and the level of vegetation density in the study area. The results of LST and NDVI analysis at the Toro hot spring point show a temperature of 23–25°C and high vegetation density conditions with a value of 0.35–0.602691. The relationship between LST and NDVI is inversely proportional, so that high vegetation conditions can affect the identification process of geothermal conditions because high vegetation absorbs heat energy released by geothermal surface features and causes lower surface temperature recording. Therefore, the surface temperature of the Toro hot springs recorded by satellite through the LST method only approaches the minimum temperature value from the 2017 KESDM data.

1. INTRODUCTION

Along with time, Indonesia's population growth will continue to grow, this will have an impact on energy needs to support daily human life and activities (Pusat Data dan Teknologi Informasi KESDM, 2017). According to Pertamina Geothermal Energy (2011), energy needs are increasing every year, but this is inversely proportional to the decreasing availability of fossil energy because the energy is included in the category of non–renewable energy. Renewable energy is the right option to replace fossil energy in sustainable energy development. Renewable energy is environmentally friendly energy that comes from sustainable natural processes such as geothermal, sunlight, wind, water, and biofuels (Media Komunikasi KESDM, 2016). Indonesia has one of the renewable energy potentials with the type of geothermal. This is supported by the geographical location of Indonesia, which is located at 3 confluences between active tectonic plates, namely the Indo–Australian Plate, the Eurasian Plate, and the Pacific Plate. The meeting of the 3 plates causes the formation of many volcanoes in Indonesia which can act as a source of geothermal energy. (Hadiwijoyo, 2011). The geothermal potential in Indonesia is 23,765.5 MWe and 2,175.7 MWe has been utilized or 9% of the total potential (KESDM, 2021)

In carrying out geothermal exploration activities, of course, it will require large costs, a very long time, as well as some accessibility that may be difficult to reach. Therefore, a comprehensive survey is needed in order to facilitate the initial analysis in conducting the exploration. Remote sensing is a technology or method that is useful for obtaining information from an object and so on without touching it directly (Lillesand et al., 2004). The remote sensing technique used in this research is the Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) methods. This method can be an alternative to identify the presence of geothermal energy in geothermal exploration and help face exploration challenges in terms of time effectiveness, economy and accessibility to exploration locations.

One of the locations in Indonesia that has geothermal potential is Toro, Central Sulawesi. This location has geothermal potential in the form of a hypothetical type of 8 MWe and geothermal manifestations in the form of Toro Hot Springs with a temperature of 25 –60 °C (Direktorat Panas Bumi KESDM, 2017). This study aims to identify the relationship between LST and NDVI to Toro hot springs. In conducting the LST and NDVI analysis, Landsat 8 OLI/TIRS data was used to determine the distribution pattern of surface temperature and the level of vegetation density in the study area.

2. DATA AND METHOD

2.1 Data

Subsection headings should be capitalized on the first letter The research method used is the study of literature and data processing consisting of Pre‒Processing, Processing, and Map‒making. The data used in this study is the type of Landsat 8 satellite imagery data obtained via USGS which is on path 114 and row 061. The satellite image data was recorded on October 21, 2019 with data collection time at 02:09:50. The data has a solar azimuth value of 112.45°, a solar elevation of 65.22°, and a cloud cover of 7.02%. However, the surface condition of the research area is in very low cloud cover. In addition to Landsat 8 satellite imagery data, data from DEM Toro, Central Sulawesi is also used.

2.2 Method

2.1.1 Pre‒Processing

In the pre‒processing stage, radiometric corrections were made to the Landsat 8 satellite image data as the research data. The purpose of making radiometric corrections is to correct and minimize surface reflection errors, sunlight direction, weather conditions, atmospheric disturbances and other factors that occur when recording satellite image data, so that the resulting information becomes more accurate (Ekadinata et al., 2008; Main et al., 2011). Another use of the correction is to analyze multi‒temporal and multi‒sensory data in interpreting and detecting continuous changes (Kustiyo et al., 2014). To obtain the calculation of the radiometric correction can be done with the equation of the algorithm, as follows:

$$L\lambda = ML * QCal + AL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Description:

Lλ = ToA radiance (Watt/m2.srad.μm)

ML = Gain sensor (Radian Multi_ Band x, where x is the band number (obtained from Landsat 8 metadata)

Qcal = Quantized and calibrated standard product (DN) pixel value

AL = Band‒specific additive scaling factor of metadata (Radiance_Add_Band_x, where x is the band number (obtained from Landsat 8 metadata)

2.1.1 Processing

At the processing stage, processing of Landsat 8 satellite image data is used as research data to obtain information about the distribution of Normalized Density Vegetation Index (NDVI) and Land Surface Temperature (LST) values from the research area.

Normalized Difference Vegetation Index (NDVI)

According to Hung (2000), the Normalized Difference Vegetation Index (NDVI) is a standard which is able to compare satellite images with a density, biomass, and greenness level. The NDVI value is based on the difference between the maximum absorption of radiation in the RED channel and the maximum reflectance in the NIR channel. In Landsat 8 imagery, RED is in band 4 which is the result of chlorophyll pigment and NIR is in band 5 which is the result of the effect of leaf cellular structure (Tucker, 1979). To obtain the results of the NDVI calculation, it can be done with an algorithm equation, as follows:

$$NDVI = (RNIR - RR) / (RNIR + RR) \ldots\ldots\ldots\ldots\ldots\ldots 2$$

Description:

NDVI = Vegetation index value

RNIR = Infrared light radiation from pixels (obtained from band 5)

RR = Red light radiation from pixels (obtained from band 4)

In analyzing the NDVI of a research area, the classification from Wahyunto (2006) is used, as follows:

Table 1: NDVI classification (Wahyunto, 2006)

NDVI Value	Description
1 <NDVI< -0.03	Non-vegetation land
-0.03 <NDVI< 0.15	Very low vegetation land
0.15 <NDVI< 0.25	Low vegetation land

0.25 <NDVI< 0.35	Medium vegetation land
0.35 <NDVI< 1	High vegetation land

Land Surface Temperature (LST)

Land Surface Temperature (LST) is a condition that is influenced by the balance of the atmosphere, surface energy, thermal properties of the surface, and subsurface media, as well as the average surface temperature of a surface described in the coverage of a pixel with various types of surface types. different (Becker and Li, 1990; Faridah and Krisbiantoro, 2014).

In obtaining the Land Surface Temperature (LST) distribution in the research area, it is necessary to first calculate the Normalized Difference Vegetation Index (NDVI), Proportion of Vegetation (PV), Emissivity (ε), Brightness Temperature (BT).

The first step is to calculate NDVI using parameters in the form of values from the Landsat 8 image, namely band 4 and band 5, as follows the equation for the NDVI calculation algorithm:

$$NDVI = (RNIR - RR) / (RNIR + RR) \qquad (3)$$

Description :

NDVI = Vegetation index value

RNIR = Infrared light radiation from pixels (obtained from band 5)

RR = Red light radiation from pixels (obtained from band 4)

After processing the data with the NDVI calculation, then the calculation of the Proportion of Vegetation (PV) is carried out because it is to find out a percentage condition of the vertical projection on vegetated land cover in an area (Ramadhan et al., 2021). To obtain the results of the PV calculation, it can be done by using the algorithm equation, as follows:

$$PV = (NDVI - NDVImin) / (NDVImax - NDVImin) \qquad (4)$$

Description :

NDVI = NDVI value (Value : $-1 < NDVI < 1$)

NDVImin = Smallest NDVI value

NDVImax = Highest NDVI value

The PV results that have been obtained are used in calculating the Emissivity (ε) value. Data processing in obtaining Emissivity (ε) is useful for minimizing errors in estimating an LST condition with Landsat 8 images used (Ramadhan et al., 2021).

$$\varepsilon = 0.004 * PV + 0.986 \qquad (5)$$

Description :

ε = Emissivity

0.004 = Average value of emissivity in the dense category

0.986 = Standard value of open land emissivity

Then, after the Emissivity (ε) calculation results are obtained, it is necessary to calculate the Brightness Temperature (BT) value which has been corrected previously, because it is electromagnetic wave radiation detected by the thermal sensor from the satellite (Ramadhan et al., 2021). For the calculation of Brightness Temperature (BT) can be done using the equation of the algorithm, as follows:

$$BT = K2/\ln(K1/L\lambda + 1) \qquad (6)$$

Description :

BT = Satellite temperature brightness (Kelvin).

K1 = Constants contained in the metadata band ($W/(m^2.sr.\mu m)$).

K2 = Constants contained in the metadata band (Kelvin).

Lλ = ToA radiance (Watt/m^2.srad.μm).

Next, an LST calculation is carried out using parameters from the identification of Landsat 8 satellite imagery, namely band 10 and band 11. To obtain an LST calculation, it can be done using the following algorithm:

$$LST = (BT/ 1 + (\lambda BT/(hc/\sigma) \ln\varepsilon) - 273 \ldots\ldots\ldots\ldots 7$$

Description :

LST = Surface temperature (Celsius).

BT = Satellite temperature brightness (Kelvin).

λ = Wavelength of radiation (11.5 m).

h = Planck's constant ($-6.626*10^{-34}$ Js).

c = Speed of light ($-2,998*10^{8}$ m/s).

σ = Boltzmann's constant ($-1.38*10^{23}$ J/K).

ε = Emissivity.

−273 = Convert temperature from Kelvin to Celsius

3. RESULTS AND DISCUSSION

From the results of the analysis through literature studies and data processing that has been carried out, the results obtained are Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) maps. These results will be discussed regarding the relationship between NDVI and LST to a geothermal manifestation, namely the Toro Hot Springs (APT).

3.1 Normalized Difference Vegetation Index (NDVI)

From the results of the Normalized Difference Vegetation Index (NDVI) analysis of the research area, it can be found that the NDVI range value is between 0.00823204 −0.602691. The vegetation density level of the research area based on Wahyunto's (2006) classification is dominated by high vegetation density, followed by low vegetation, medium vegetation, and non-vegetated land. So it can be observed in Figure 1, that the closer the vegetation index value is to 1, the denser the vegetation level will be and vice versa.

Based on the map in Figure 1, the Toro Hot Springs (APT) is located in the research area with high vegetation type conditions.

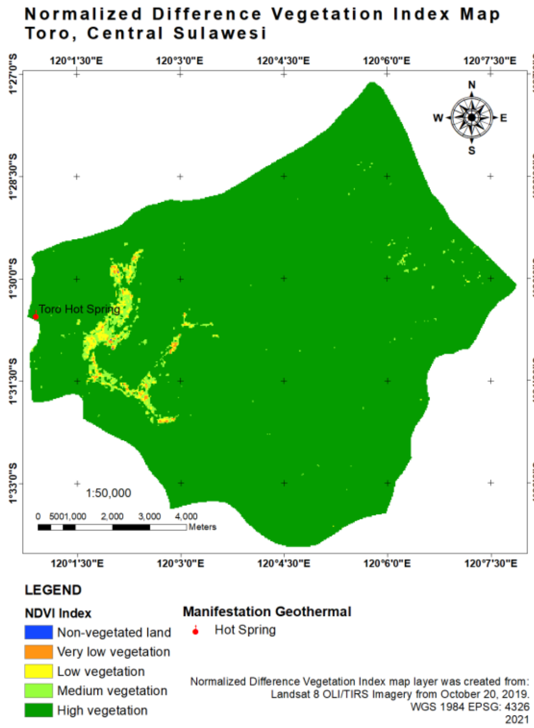

Figure 1: Normalized Difference Vegetation Index (NDVI) Map of Toro, Central Sulawesi.

3.2 Land Surface Temperature (LST)

From the results of the analysis through the literature study and data processing that has been carried out, the LST map (figure 2) is obtained which represents the temperature level of the research area with temperature values ranging from 17.3738−27.2241°C. With the LST method, it can be seen that the surface temperature distribution of the research area is associated with geothermal manifestations such as the Toro Hot Spring which is at a temperature of 23−25°C. The higher the temperature on a surface, the more likely an area has geothermal potential (Zhang, 2012).

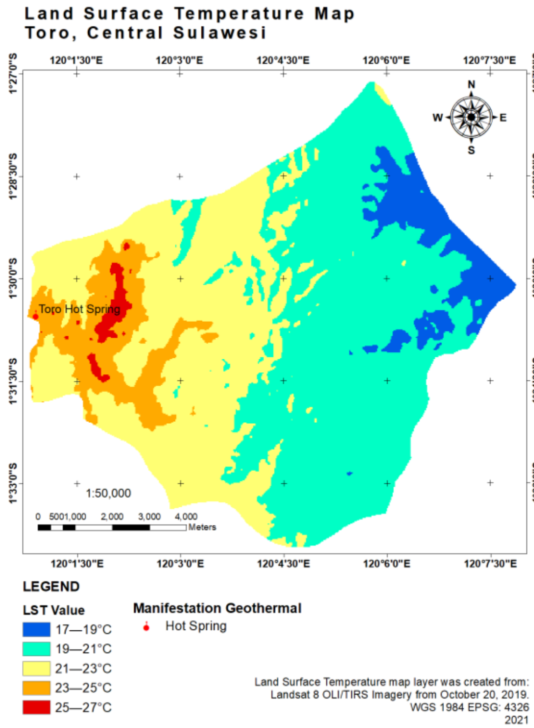

Figure 2: Map of Land Surface Temperature (LST) Toro, Central Sulawesi.

3.3 Relationship Between LST (°C) and NDVI

From the results of the correlation between LST and NDVI, that the relationship between LST and NDVI is almost close to negative linear regression, where if observed in table 1, information is obtained on LST conditions in the research area with NDVI in the range of 0.35—1 at a temperature of 15—23 °C and The NDVI range below 0.35 is at a temperature of 23—27°C. So, if in an area the vegetation level is higher, the temperature will decrease (Maharani et al., 2021).

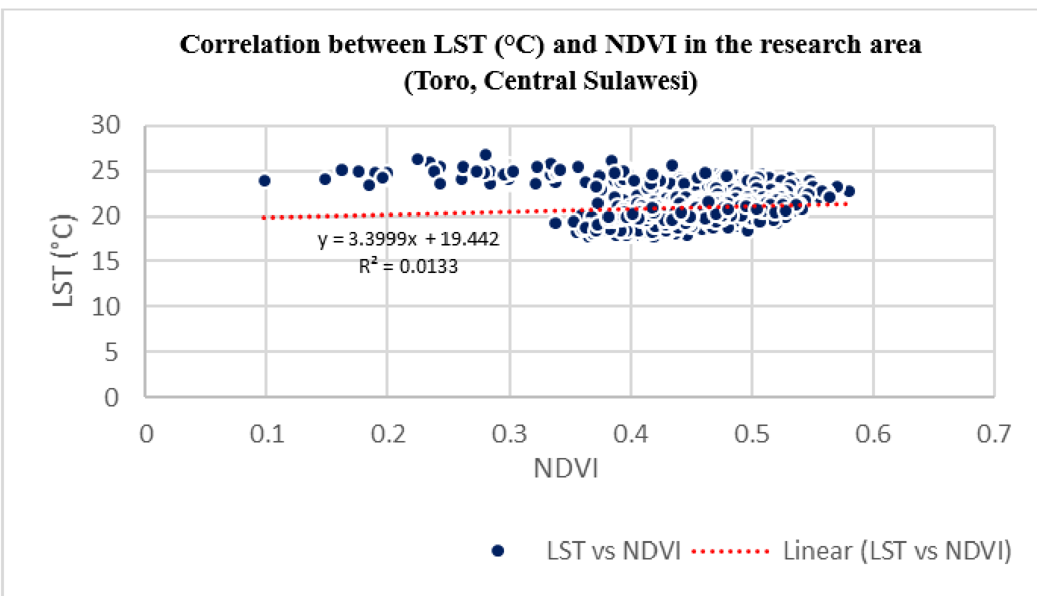

Figure 3: Correlation between LST (°C) and NDVI in the research area (Toro, Central Sulawesi).

3.4 Relationship Between Toro Hot Springs (°C), LST (°C) and NDVI

It can be observed in Figures 1 and 2 the location of the manifestation point is in high vegetation conditions with a temperature range of 23–25°C. However, if it is associated with data from ESDM (2017), the temperature conditions of Toro Hot Springs have a range of 25–60°C. From this, it is found that high vegetation conditions can affect the identification process of geothermal conditions because tall vegetation absorbs heat energy released by geothermal surface features and causes lower surface temperature recording.

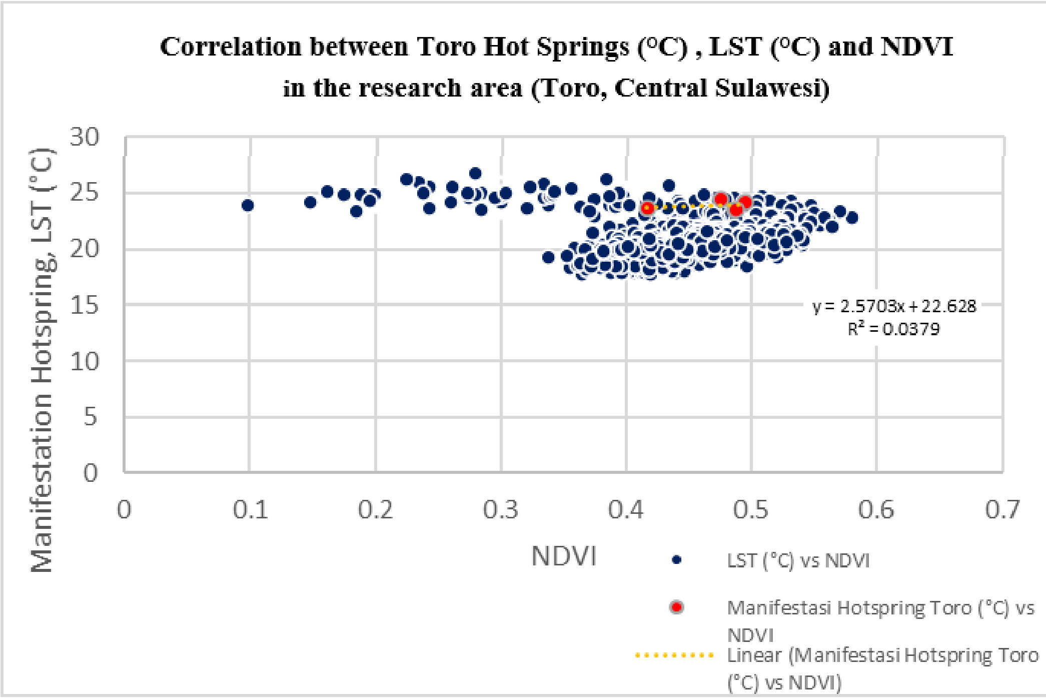

Figure 4: Correlation between Toro Hot Springs (°C) , LST (°C) and NDVI in the research area (Toro, Central Sulawesi).

4. CONCLUSION

From the results of LST and NDVI analysis at the Toro hot spring point show a temperature of 23–25°C and high vegetation density conditions with a value of 0.35–0.602691. The relationship between LST and NDVI is inversely proportional, so that high vegetation conditions can affect the identification process of geothermal conditions because high vegetation absorbs heat energy released by geothermal surface features and causes lower surface temperature recording. Therefore, the surface temperature of the Toro hot springs recorded by satellite through the LST method only approaches the minimum temperature value from the 2017 KESDM data.

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