The determination of geothermal potential area based on remote sensing, Micromine software, and land surface temperature calculation

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Abstract. Indonesia has a significant geothermal energy potential because it is in the Ring of Fire. However, only 7% of identified potential geothermal has been utilized until now. This research aims to determine and predict geothermal potential area by using Landsat 8 imagery, Micromine software, and Land Surface Temperature Calculation. Land Surface Temperature calculation can be carried out by thermal infrared bands which can be obtained from Landsat 8 imagery. Land Surface Temperature calculation is based on a Split-Window algorithm which providing a surface temperature value and its distribution. Furthermore, the method can support to generate the distribution of Land Surface Temperature in research area using Micromine software. The remote sensing analysis also being done to determine geological structures development in the research area which assumed to control manifestation occurrence. It also shows the appearances of geothermal surface manifestation. The result of Land Surface Temperature analyses could predict surface temperature zone in the research area. The area that has high surface temperature value tends to be an area that has a potential geothermal area. The application of this method is being done on a potential geothermal field around Mt. Patuha, Ciwidey, West Java to verify these approaches. This research shows that Land Surface Temperature method to determine geothermal potential has a positive result.

1. Introduction
Landsat satellite continuously takes imageries of the earth’s surface from space and provide valuable data since 1972. One analysis that can be done with Landsat imagery is Land Surface Temperature (LST) analysis. LST is temperature felt when the land surface is touched with the hands or can be defined as the skin of the ground [1].

LST is one key energetic equilibrium parameters on the surface and is also a major climatological variable [2]. The utilization of this LST is used further in this research, that is to estimate geothermal potential areas based on the distribution of the LST obtained using remote sensing. The utilization of LST for geothermal potential area estimation was carried out around Mt. Patuha, Ciwidey, West Java as the research area to prove the validity of this method.

2. Methodology
Two methods are used in this research, i.e. lineament delineation and calculation of LST in the 5x5 km of the research area. Lineaments delineation is performed on a digital elevation model (DEM) represented from four directions of illumination which support each other to optimize the showing of lineaments in the delineation step [3]. Illumination angles of 0°, 45°, 90°, and 135° are used in this
research. This is done with the aim of estimating fractures that can be assumed to be the pathway of thermal water to the surface.

The 8th version of Landsat imagery has a total of 11 bands with their respective uses and also two types of sensor, i.e., Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) [4]. Land Surface Temperature (LST) utilizes some bands from those bands contained in a Landsat 8 imagery. However, the main parts of LST calculations are the 10th and 11th band.

LST calculations are broken down into several stages using the Split-Window algorithm [5,1].

![Flowchart of split-window algorithm](image)

Figure 1. Flowchart of split-window algorithm [5,1].

Split-Window algorithm is an algorithm that is prepared to simplify the calculation of surface temperature using the following formula:

\[
LST = TB_{10} + C_1 (TB_{10} - TB_{11}) + C_2 (TB_{10} - TB_{11})^2 + C_0 + (C_3 + C_4W) (1 - \varepsilon) + (C_5 + C_6W) \Delta \varepsilon
\]

where:

- LST: Land Surface Temperature (K)
- C0-C6: Split-window coefficient (table 1) (Rajeshwari & Mani, 2014; Skokovic et al., 2014).
- TB10 and TB11: Brightness temperature of 10 and 11 bands (K). TB10 and TB11 can be determined by formula \( TB = K2/L\lambda ((K1/ L\lambda) + 1) \)

where:

- K1 and K2: thermal conversion constant of 10 and 11 bands.
- L\lambda: Top of atmospheric spectral radiance (m².srad.µm). L\lambda can be determined by \( L\lambda = ML \times Qcal + AL \)

where:

- ML: multiplicative rescaling factor of 10 and 11 bands. ML can be known directly from Landsat attached note = 0.000342
- Qcal: the value of 10 and 11 bands themselves.
- AL: additive rescaling factor of 10 and 11 bands. AL can be known directly from Landsat attached note = 0.1
• $\varepsilon$: mean of Land Surface Emissivity of 10 and 11 bands. $\varepsilon$ can be determined from $\varepsilon : (\varepsilon_{10} - \varepsilon_{11}) / 2$

• $\Delta \varepsilon$: difference of Land Surface Emissivity of 10 and 11 bands. $\Delta \varepsilon$ can be determined from $\Delta \varepsilon : \varepsilon_{10} - \varepsilon_{11}$ where $\varepsilon_{10}$ and $\varepsilon_{11}$ are the value of Land Surface Emissivity. Each emissivity value of 10 and 11 bands can be determined from $\varepsilon = \varepsilon_s (1 - FVC) + \varepsilon_v * FVC$

where:

- FVC: Fractional Vegetation Cover. FVC of 10 and 11 bands with formula $FVC = (NDVI - NDVI_s) / (NDVI_v - NDVI_s)$

- NDVI: Normalized Difference Vegetation Index. NDVI can be determined from $NDVI = ((B5) - (B2))/((B5) + (B2))$ where $B_n$ is the value of the bands contained in Landsat.

- NDVI_s: soil NDVI. NDVI_s can be determined from $NDVI_s = ((B5) - (B4))/((B5) + (B4))$ where $B_n$ is the value of the bands contained in Landsat.

- NDVI_v: vegetation NDVI. NDVI_v can be determined from $NDVI_v = ((B5) - (B3))/((B5) + (B3))$ where $B_n$ is the value of the bands contained in Landsat.

- $\varepsilon_s$: Soil Emissivity [1,6].

- $\varepsilon_v$: Vegetation emmisivity[1,6].

| Parameter | Desc. | Value |
|-----------|-------|-------|
| $C_0$ | | 0.268 |
| $C_1$ | | 1.578 |
| $C_2$ | | 0.183 |
| $C_3$ | | 0.340 |
| $C_4$ | | 2.238 |
| $C_5$ | | 0.229 |
| $C_6$ | | 0.400 |
| ML Band 10 | Multiplicative Rescaling Factor of Band 10 | 0.000342 |
| ML Band 11 | Multiplicative Rescaling Factor of Band 11 | 0.000342 |
| AL Band 10 | Additive Rescaling Factor of Band 10 | 0.1 |
| AL Band 11 | Additive Rescaling Factor of Band 11 | 0.1 |
| $\varepsilon_s$ Band 10 | Soil Emissivity of Band 10 | 0.971 |
| $\varepsilon_s$ Band 11 | Soil Emissivity of Band 11 | 0.977 |
| $\varepsilon_v$ Band 10 | Vegetation Emissivity of Band 10 | 0.987 |
| $\varepsilon_v$ Band 11 | Vegetation Emissivity of Band 11 | 0.989 |
| K1 Band 10 | Thermal Constant K1 of Band 10 | 7748.853 |
| K1 Band 11 | Thermal Constant K1 of Band 11 | 1321.0789 |
| K2 Band 10 | Thermal Constant K2 of Band 10 | 480.8883 |
| K2 Band 11 | Thermal Constant K2 of Band 11 | 1201.442 |

Landsat imagery used in this research is Landsat version 8 with 15 meter resolution captured by satellite on 24th September 2018 which is the latest research area image data at the time this research was conducted.

LST calculation results using the 11 bands from Landsat imagery will produce maps of LST distribution that are mapped using Micromine software. The LST distribution map will be compared with the results lineament delineation and manifestations location to find out the similarity of the analysis results of those elements.

3. Results and discussion

3.1. Lineament delineation
Delineation is carried out in the research area and produces a distribution of lineament with varying orientations. Lineaments are delineated from the direction of light 0, 45, 90, and 135 degrees are respectively distinguished by red, orange, yellow, and blue in the map below.

![Lineament Delineation](image)

**Figure 2.** Lineament delineation of the research area.

3.2. *Land surface temperature calculation*

LST calculations are done manually using Microsoft Excel data processing. Steps in using LST calculation formula to get LST value of each Landsat resolution are carried out by following the Split-Window algorithm [5,1].

The results of the calculations are converted onto a map that shows the distribution of surface temperature which can be seen in figure 3. The results of the calculation show that the average surface temperature in the study area is calculated at 16.73 ° Celsius with a temperature range in the study area is 32.89.

It can be seen from the results of the distribution of the LST in the figure above, the western part of the research area has a relatively higher temperature compared to other areas. There are areas with an LST value between 20°C-25°C located in the Kawah Putih area. Kawah Putih is one of the craters of Patuha Mountain in the form of a crater lake which has color due to high sulfur content and a certain temperature, which causes the surrounding rock and sand to become white, hence the name [7].

The temperature of the water in the Kawah Putih is quite stable throughout the year between 30°C-34°C. This temperature shows a positive result of LST distribution which is proved by successfully identifying relatively higher temperatures area in Kawah Putih.

In the northwestern part of the study area, there is a known hot spring named Ciwalini hot spring that is used by residents to be used as tourist attractions. The hot spring is located in an LST with a value between 20°C-25°C. This hot spring is proof that there is a potential geothermal in the northwestern part of the study area.
The results of lineament delineation and LST distribution are compared to each other. The results indicate that Kawah Putih and Ciwalini hot springs are closely located to delineated lineament. Kawah Putih is shown to be located on the northern side of an E-W oriented lineament, while Ciwalini hot spring is located on the northern side of a lineament with NW-SE orientation. In addition, in the eastern part of Patuha Mountain has a relatively higher lineament density, but there is no manifestations of hot water were found.

The explanation above shows that LST analysis in identifying geothermal potential areas has positive results. Both geothermal manifestations in the research area are located in regions with relatively higher LST values than other regions. The utilization of LST in identifying geothermal potential deserves further investigation for more optimal utilization and can be used in other similar research.

4. Conclusion

After all the methods are carried out in this research, i.e. lineament delineation and calculation of LST distribution in the research area with geothermal manifestations, it can be concluded that the application of LST analysis to determine geothermal potential areas shows positive results. This conclusion is drawn based on the result that shows all the compared elements show a relationship with each other. Further studies need to be carried out to optimize the utilization of LST and also to find out all factors that need to be considered in further utilization.

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