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IDENTIFICATION OF LAND SURFACE TEMPERATURE DISTRIBUTION OF GEOTHERMAL AREA IN UNGARAN MOUNT BY USING LANDSAT 8 IMAGERY

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Abstract. Indonesia located at the confluence of Eurasian tectonic plate, Australian tectonic plate and the Pacific tectonic plate. Therefore, Indonesia has big geothermal potential. One of the areas that has geothermal potential is Ungaran Mount. Remote sensing technology can have a role in geothermal exploration activity to map the distribution of land surface temperatures associated with geothermal manifestations. The advantages of remote sensing are able to get information without having to go directly to the field with a large area, and it takes quick, so that the information can be used as an initial reference exploration activities. This study aimed to obtain the distribution of land surface temperature as a regional analysis of geothermal potential. The method of this research was a correlation of brightness temperature (BT) Landsat 8 with land surface temperature (LST) MODIS. The results of correlation analysis showed the R^2 value was equal to 0.87, it shows that between BT Landsat 8 and LST MODIS has a very high correlation. Based on Landsat 8 LST imagery correction, the average of fumarole temperature and hot spring is 24^0C. Fumarole and hot spring are located in dense vegetation land which has average temperature around 26.9^0C. Land surface temperature Landsat 8 can not be directly used to identify geothermal potential, especially in the dense vegetation area, due to the existence of dense vegetation which can absorb heat energy released by geothermal surface feature.

Keywords: *land surface temperature, Landsat, MODIS, geothermal, Ungaran*

1 INTRODUCTION

Indonesia located at the confluence of Eurasian tectonic plate, Australian tectonic plate and the Pacific tectonic plate. This condition make it is possible for the formation of regions that have geothermal potential. Subduction zones of the Eurasian and Australia plate along about 4000 km, it creates around ± 200 volcanoes and 100 geothermal fields in Indonesia (Setyaningsih, 2011). Based on the surface area of geothermal potential, Indonesia places in the world fourth rank, and in the second rank based on the temperature (Wahyuningsih, 2005). Geothermal is a natural heat resource in the earth, it is the result of interaction between the hot rocks and groundwater surrounded, where the heated water is trapped in rocks that located near the surface, so it can economically exploited (Armstead, 1983).

One of the areas in Indonesia that have geothermal potential is in the area of Ungaran Mount, Semarang regency, Central Java. From Figure 1-1, it can be seen on the northern slopes of Ungaran Mount there are hot springs and the southern slopes are Fumarole and alteration hydrothermal. The existence of hot springs, Fumarole, and hydrothermal alteration are commonly used to estimate the geothermal area (Faridah, 2014). Generally, the feature of the surface geothermal manifestations are shown by the hot springs, hot land, fumarole, and geysers (Yunus, 1993). According to the estimation, geothermal prospects of Ungaran Mount are dominated by water domination system, which is controlled by Ungaran caldera structure. The heat source is estimated to be a dioritic intrusion. Cracked volcanic rocks which are in the early quatneary and tertiary age are expected as a reservoir rock. On the other hand, impermeable volcanic rocks in the end quaternary age are expected as the covering rock. Based on geothermometry on the fumaroles in Gedongsongo region, reservoir temperature is estimated at 230 ºC (Wahyudi, 2006).

Remote sensing technology can be used in geothermal exploration activity to map the distribution of surface temperatures associated with geothermal manifestations (Faridah, 2014). The advantages of remote sensing is we can find out a condition without having to go directly to the field with a large area, so that the data generated by remote sensing technology can be used as a starting point when conducting surveys directly to the field. This makes the field survey is more effective and efficient, because it does not need to cover the entire work area, just in the area-areas that are predicted geothermal potential.

The surface temperature can be identified using satellite imagery that has thermal sensors, such as TIRS imagery (Thermal Infra Red Sensor) Landsat 8 satellite with a resolution 100 m and MODIS imagery with a resolution 1000 m. Recently, research on the soil surface temperature is already conducted by using various methods, such as Split window algorithm method, single channel algorithm, SEBAL method (Rozeinstein *et al.*, 2014; Kamran *et al.*, 2015; Benmecheta *et al.*, 2013; Du *et al.*, 2015; Kurnia *et al.*, 2016). Utama (2012) in his research, specifically describes the use of sensors TIRS Landsat 8 in early review of the determination of the alleged potential geothermal areas in Lamongan, the method used was in the form of brightness temperature image.

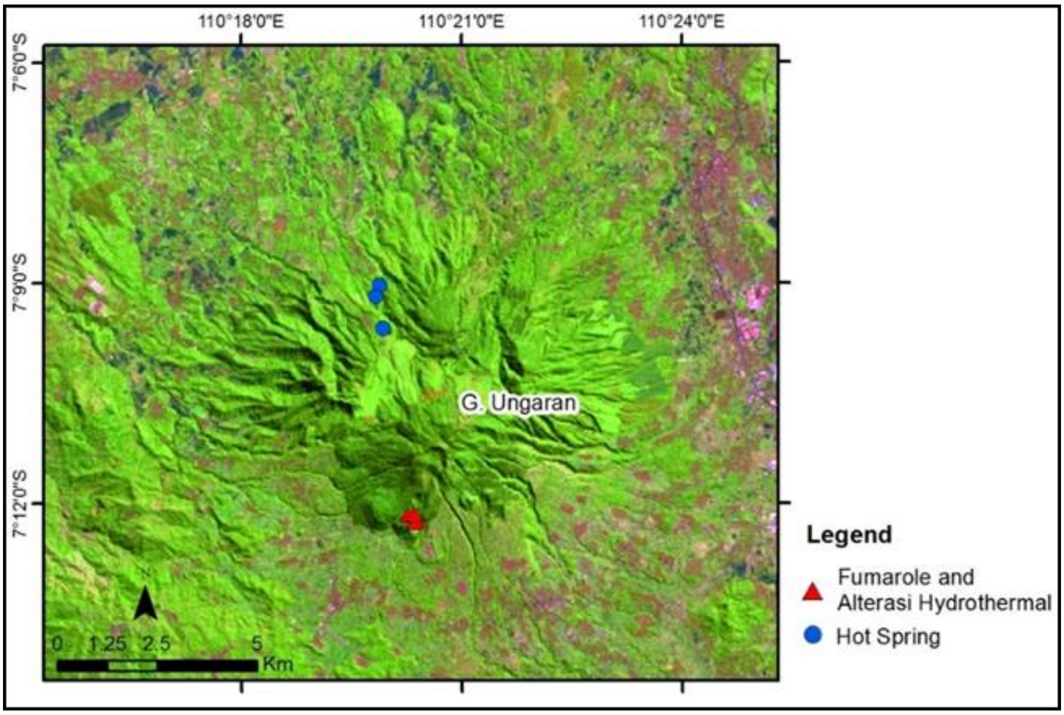

Figure 1-1: Landsat 8 RGB 653 of Ungaran Mountain

This study aimed to obtain land surface temperature distribution for analysis of potential geothermal areas in Ungaran Mount. The method used was a correlation of brightness temperature Landsat 8 with MODIS land surface temperature. MODIS imagery used as a reference was MOD11, since that image has high land surface temperature accuracy (Wan *et al.*, 2002).

2 MATERIALS AND METHODOLOGY

2.1 Data

The data used was Landsat 8 path 120 row 065 which were acquired on June 30, 2015, Landsat data can be obtained through the website for free in bdpjn-catalog.lapan.go.id. As a reference, the researcher used MODIS mosaic MOD11 data for 8 days period of June 27, 2015 - July 4, 2015 which can be obtained through the website lpdaac.usgs.gov/data_access/data_pool. The researcher used MODIS mosaic in 8 days, as to minimize the presence of clouds (clouds can be noise).

2.2 Data Processing

2.2.1 Temperature brightness

The first thing to do is to convert the digital number on Landsat 8 becomes spectral radiance by using the following equation (USGS, 2015):

$$L_\lambda = M_L Q_{cal} + A_L \qquad (2\text{-}1)$$

Where:

L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))

M_L = Band-specific multiplicative rescaling factor from the metadata RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

The result of spectral radiance conversion is then processed with brightness temperature by using the following equation (USGS, 2015):

$$T\_Landsat = \frac{K2}{\ln\left(\frac{K1}{L\lambda}+1\right)} - 273 \qquad (2\text{-}2)$$

Where:

T = At-satellite brightness temperature (C)

L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

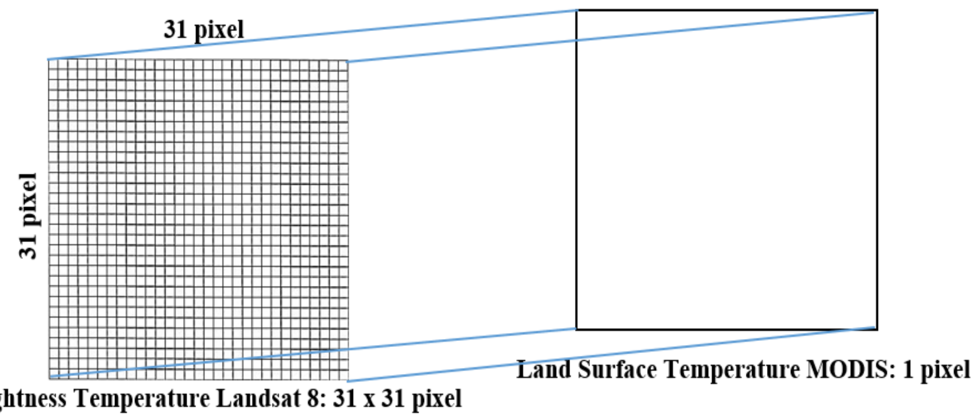

Figure 2-1: Correlation brightness temperature Landsat 8 and MODIS land surface temperature

2.2.2 Correlation Method

To obtain the equations used to correct the brightness temperature Landsat 8 to become lands surface temperature Landsat 8, further, we c onducted correlation analysis between MODIS land surface temperature imagery data and brightness temperature landsat 8. Since, there is differences resolution between land surface temperature MODIS (1 km) and brightness temperature Landsat 8 (100 m resample to 30 m), then the correlation analysis applies to the window 31 x 31 pixel Landsat 8 with 1 x 1 pixel MODIS (Figure 2-1).

Correlated data are the averaged temperature values of each window 31 x 31 pixels of Landsat 8 with MODIS temperature value at 1 pixel. Each window 31 x 31 pixels of Landsat 8 is calculated the value of its coefficient of variance and selected which has a coefficient of variance of less than 10%. The smaller the value of coefficient of variance, the more homogeneous the pixel values are. After correlation analysis is done, linear equations were obtained. It is used to correct the brightness temperature (BT) Landsat 8 to lands surface temperature (LST) Landsat 8.

2.2.3 Enhanced Vegetaion Index (EVI)

Enhanced Vegetation Index (EVI) is a method in determining the level of greenness and biomass which has been developed to optimize the better signal sensitivity vegetation in areas of high biomass. EVI is more responsive to variations in the canopy structure determination, including the Leaf Area Index (LAI), canopy type, fisiogonomi plant and canopy architecture (Hafiz *et al.*, 2013). The equation used to calculate EVI is as follows (Huete *et al.*, 1997):

$$EVI = G \, X \, \frac{\rho nir - \rho red}{\rho nir + (C_1 \, X \, \rho red + C_2 \, X \, \rho blue) + L} \tag{2-3}$$

where ρ is the reflectance value. To be resistant to atmospheric distortion, EVI uses blue light channel information. C1 and C2 variable in the equation above is the weighting factor to overcome aerosol, while the variable L is a calibration factor the effect of the canopy and the ground, while G is a scaling factor in order to make EVI values are in the range -1 to 1.

3 DISCUSSION

Based on statistical calculations on the area of interest (AOI) BT imagery Landsat 8 imagery 31x31 pixel (called 1 window), we can see that a coefficient of variance is less than 10%, it is as much as in 2442 from 2462 total windows. The results of the correlation analysis between the average of the pixel values on 1 window of brightness temperature Landsat 8 imagery and one pixel LST MODIS value, we obtained in a linear equation y = 1.1959x - 2,432 with a value of R^2 = 0.87. R^2 value close to 1, indicates between BT Landsat 8 with LST MODIS has a high correlation, or interconnected so that the equation can be applied to correct the brightness temperature of Landsat 8 become land surface temperature Landsat 8 (Figure 3-1).

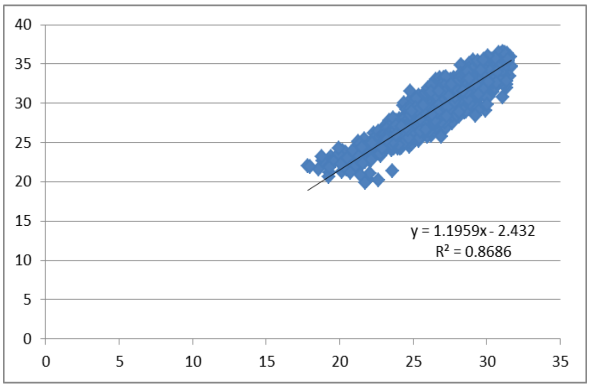

Figure 3-1: Graph of correlation BT Landsat 8 and LST Modis 11

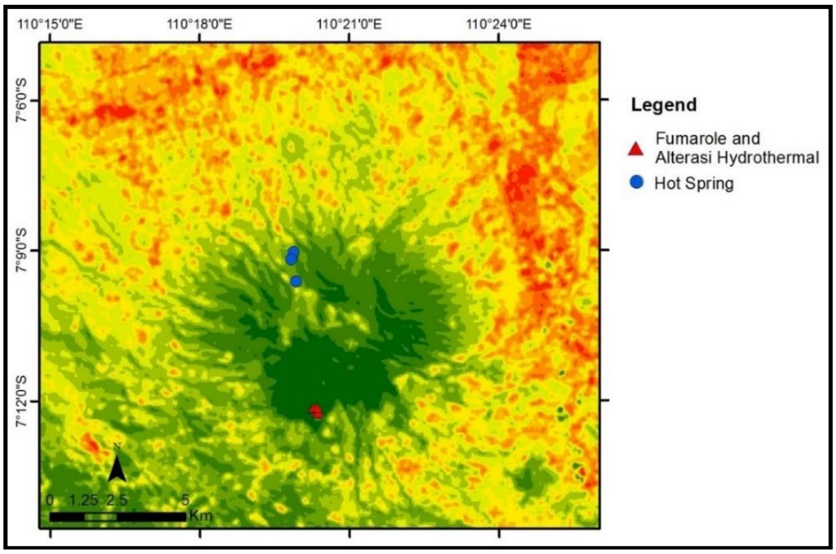

Figure 3-2: LST Image Landsat 8 Gunung Ungaran

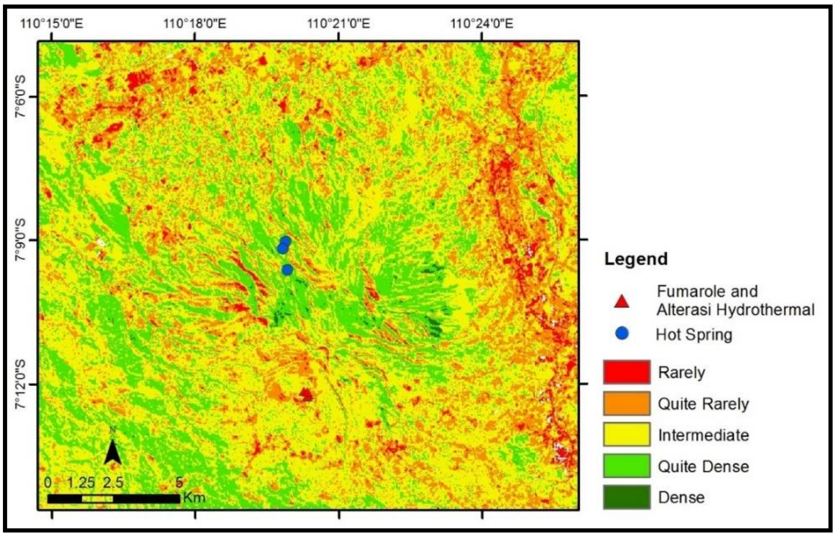

Figure 3-3: Information vegetation density based on the EVI Landsat 8

The average temperature of fumarole and hot spring based on image LST Landsat 8 is 24 ºC. The temperature scale is different from field measurements performed by Wahyudi (2006), the surface temperature fumaroles on the location of the area was around 80 ºC. The significant difference between the land surface temperatures by Landsat 8 with land surface temperature field measurements was caused by the dense vegetation around the fumarole site, further, the vegetation around fumaroles can cover the distribution of thermal energy emitted by the fumaroles.

Based on EVI Landsat 8 imagery, vegetation cover on Ungaran mountain and surrounding can be grouped into five classes, that is dense, quite dense, intermediate, quite rare, rarely. From the surface temperature distribution on each vegetation cover (Table 3-1) can be seen that the dense vegetation cover has the lowest average surface temperature, and the rarely vegetation cover has the highest average temperature. The vegetation can reduce the surface temperature, because the vegetation is able to absorb heat energy from the surface or cover the surface of the sun's heat energy.

Table 3-1: The relationship between the density of vegetation with a surface temperature of Landsat imagery LST 8

Density	LST (⁰C)				
	Average	Min	Max	Standard Deviation	Coefficient Variation
Rare	30.9	18.0	38.4	3.6	0.12
Quite rare	29.9	18.0	38.4	3.1	0.11
Intermediate	27.9	18.3	36.4	2.5	0.09
Quite dense	26.9	19.7	35.8	2.0	0.08
Dense	26.0	21.3	32.0	1.9	0.08

The location of Fumarole and hot springs are found in quite dense vegetation areas. A minimum value of the surface temperature in a quite dense vegetation density is 19.7 ⁰C, while the maximum value is 35.8 ⁰C and the average temperature is 26.9 ⁰C. The fumarole average temperature and hot springs in comparison with the average surface temperature value in a quite dense vegetation density is still below-average. The existence of a massive volcanic rock lithology as topsoil layer (Gaffar, 2007) also affects the surface temperature. Hard rock makes high surface temperatures increase and affect the temperature of the average in vegetated areas.

4 CONCLUSION

Land surface temperature MODIS imagehas a high correlation with the image brightness temperature Landsat 8, so it can be used as a reference to get the land surface temperature imagery Landsat 8, although it should be tested comprehensively with more data coverage in a different location. Land surface temperature Landsat 8 cannot be directly used to gain geothermal potential, especially in quite dense vegetation area, due to the existence of quite dense vegetation can absorb heat energy released by geothermal surface feature.

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