Geothermal Potential Analysis Using Landsat 8 and Sentinel 2 (Case Study: Mount Ijen)

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Abstract. Geothermal energy is also a heat energy contained in the earth's internal. Indonesia has a total geothermal potential of around 27 GWe. The government is eager for the development of geothermal in Indonesia can run well so that geothermal can act as one of the pillars of national energy. However, the geothermal potential has not been fully utilized. One of the geothermal potention is Mount Ijen. Mount Ijen is a strato volcano that has a crater lake with a depth of about 190 m and has a very high degree of acidity and the volume of lake water is very large. With the abundance of potential geothermal potential in Indonesia, it is necessary to have an activity in the form of integrated geoscience studies to be able to maximize the potential content that exists in a geothermal area. One of the studies conducted is to do potential mapping. This research performs image data processing of Landsat 8, Sentinel 2, RBI Map, and preliminary survey data. This research carried out the Vegetation Index, surface temperature and altitude. The equipment used in this research includes image processing software, number processing software, GPS Handheld and Laptop. Surface Temperatures in the Mount Ijen have anomalies with large temperatures ranging between 18^{o} C to 38^{o} C. The best correlation value of altitude and ground surface temperature is -0.89 ie the correlation of January surface temperature. While the correlation value of Landsat 8 and Sentinel 2 vegetation index was 0.81. The land cover confidence matrix scored 80%. Land cover in the research area is dominated by forests by 35% of the research area. There is a potential area of geothermal potential is very high on Mount Ijen with an area of 39.43 hectares located in Wongsorejo District and adjacent to District Sempol.

Keywords: Geothermal, Landsat 8, Sentinel 2, Surface temperature, Vegetation index

1. Introduction

A total of 252 geothermal locations in Indonesia are scattered following the path of volcanic formation that stretches from Sumatra, Java, Nusa Tenggara, Sulawesi to Maluku. With a total potential of around 27 GWe [12]. Judging from the appearance of geothermal on the surface per unit area, Indonesia ranks fourth in the world, even in terms of high temperatures, is the second largest.

The government is eager for the development of geothermal in Indonesia can run well so that geothermal can act as one of the pillars of national energy. It is seen through the stipulation of Presidential Regulation no. 5 of 2006 on National Energy Policy (KEN). In the Presidential Regulation,

the Government targets geothermal energy contribution in 2025 of 9500 MW [4]. However, geothermal potential in Indonesia is only 4% of potential that has been utilized [5].

One source of geothermal energy stored in Indonesia is located on Mount Ijen. Mount Ijen is located in District Licin and District Sempol, Banyuwangi and Bondowoso, East Java. The height of the crater lake of Mount Ijen reaches 2145 m and the edge of the crater reaches 2386 from sea level. Currently Ijen crater measuring about 1160 m x 1160 m, with a crater lake Ijen measuring about 910 m x 600 m and has a depth of up to 200 m [1].

Geothermal energy is one of the renewable energy that can be used as an alternative because the energy made from fossil raw materials increasingly rare. The energy is clean and is considered safer because it does not require large space for exploration and exploitation purposes. In addition to geothermal energy produces steam that can be mixed also into the air [1]. In addition, geothermal is a renewable, potentially enormous, state-controlled natural resource and plays an important role as a source of energy of choice in national energy diversity to support sustainable national development for the realization of people's welfare [8].

Utilization of geothermal energy is one of the government's efforts in the diversification of energy sources. Planned in 2010 has produced 3600 MW of electrical energy from geothermal heat. This policy attracts many foreign investors, even lately, the hotbed areas with a production potential of around 20 MW also attract investors [11].

With the abundance of potential geothermal potential in Indonesia, it is necessary to have an activity in the form of integrated geoscience studies to be able to maximize the potential content that exists in a geothermal area. One of the studies conducted is to do potential mapping. Where the usefulness of the potential map is to describe geospatial information from a geothermal region to determine the potential area of the geothermal content. To pursue these targets required mastery of technology and science management of geothermal energy in a relatively very short time

Current technological advances in the field of remote sensing should be put to good use. Utilizing remote sensing technology that has high observation accuracy and relatively low cost for broad unity, thus providing the possibility to integrate the level of accuracy and efficiency in the supply of geothermal data and information. Using Landsat 8 satellite images we can obtain the values of vegetation density and ground surface temperature of the area while using DEM from the RBI map is used to obtain the height of the land formed from the digital elevation model of an area and for the land cover map using the analysis of the Landsat image 8 and Sentinel 2.

2. Materials and Methods

2.1. Research Site

The location of this study took the location of study Ijen volcano is a strato crater volcano located in the District Tetelan and District Sempol, Banyuwangi and Bondowoso, East Java. This mountain is about 33 km from Banyuwangi with geography position about 8 ° 3.5 'South and 114 ° 14.5' East:

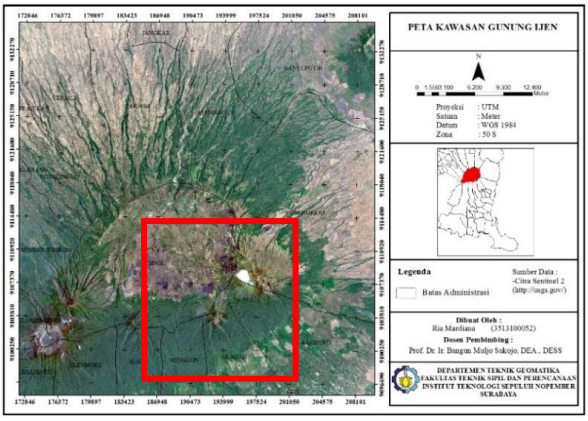

Figure 1. Research Site

2.2. Data and Equipment

2.2.1. Data. The data used in this research are:

1. Landsat Image 8 January, May and August 2016 (http://usgs.gov/).
2. Geothermal preliminary survey data on Mount Ijen are geological data, geochemical data, and geophysical data (PT Medco Power Indonesia)
3. Sentinel Image 2nd of October 2015 (http://usgs.gov/).
4. Map RBI scale 1: 25.000 Sub Sempol and Tetelan (Department of Geomatics Engineering).

*2.2.2.Equipment.*Equipment used in this research are:

1. Hardware
   a. Laptop
   b. GPS Handheld
2. Software
   a. Image processing software
   b. Software calculatating data

2.3. Step to Processing Data

The process of data processing performed can be seen will be explained as follows:

1. Cropping the image of Landsat 8 and Sentinel 2 in the desired area to facilitate data processing as it focuses more on the research area.
2. Geometric correction to coordinate the image in accordance with the coordinates of field conditions. This process is done by placing the Ground Control Point (GCP) point in the uncorrected image based on the image that has been corrected by RBI Map 1: 25000. The image can be said to be corrected if it meets the tolerance limit based on the value of RMS Error ≤ 1 pixel and SOF ≤ 1.
3. Make a radiometric correction to change the Digital Number (DN) value to Spectral Radiance. Radiometric correction aims to improve distortion due to atmospheric disturbances during image recording process. In addition, geometric correction is done so that the coordinates on the map are the same as the coordinates in the field.
4. To obtain land cover map on Sentinel 2 image, the method used is supervised classification with maximum likelihood method. Performed by determining the training area where a sample pixel area is defined as a certain type of land cover. The sampling area for this type of land cover is based on the interpretation of the image and the RBI map. After obtaining several samples representing the type of land cover in the study area, then classified by using the maximum likelihood algorithm.
5. Landsat 8 image processing to obtain vegetation density map (NDVI) and surface temperature map. The bands used to obtain surface temperature values are bands 10 and 11 while to get the value of vegetation density used band 4 and 5. Do also sentinel processing 2 to get the value of vegetation density using bands 8 and 4.
6. Processing DEM data from digitization the next RBI map of DEM data is converted to TIN surface format showing the surface model of the earth in the research area. So get the height in the area under study.
7. Digitizing geological maps to obtain geological data if a site is found fumarole and hot springs, it is undoubtedly underneath there is a geothermal source that makes the ground water temperature increase and of course only be in certain locations with typical geological conditions. Easy observation is to look for the existence of manifestation make it out surface soil as hot water so it can be used as an analysis when overlay.
8. Overlay all data then analyse geothermal potential.

3. Result and analysis

3.1. Geometric Corrections and Calculations of Strength of Figure

The design of the control point nets used in the geometric correction of images as follows:

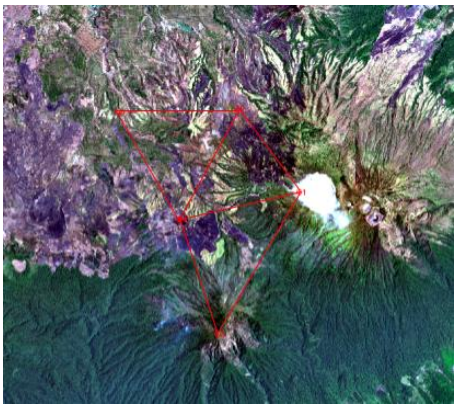

Figure 2. Design of Point Control

The calculation of SOF (Strength of Figure) of the net is:

Number of Baseline : 16
Point Count : 4
N Size : The number of Baseline x 3: 16 x 3 = 48
N Parameters : Number of Points x 3: 4 x 3 = 12
U : N Size - N Parameters: 48 - 12 = 36

SOF: Trace $\frac{Traces\,[A^T x\, A]^{-1}}{u}$: 0,088 (1)

3.2. GCP calculation and RMS Error Value

The process of giving GCP to the image is done by using image data processing software, that is by using Image to map menu using RBI map. The geometric correction of Landsat 8 and Sentinel 2 satellite images is done using 5 selected GCP dots are the same object in the image and on the reference where the possibility of change is relatively slow (fixed) such as the peak of the mountain and the edge of the cliff. The RMS error value in Landsat 8 image is 0.0003.

	Map X	Map Y	Image X	Image Y	Predict X	Predict Y	Error X	Error Y	RMS
#1+	195485.00	9108268.00	3417.59	1575.82	3417.6119	1575.8232	0.0219	0.0032	0.0222
#2+	193457.00	9110910.00	3350.05	1487.70	3350.0201	1487.6956	-0.0299	-0.0044	0.0302
#3+	192943.00	9103666.00	3332.95	1729.27	3332.9263	1729.2665	-0.0237	-0.0035	0.0239
#4+	191647.00	9107351.00	3289.69	1606.36	3289.7220	1606.3647	0.0320	0.0047	0.0323
#5+	189602.00	9110740.00	3221.55	1493.38	3221.5497	1493.3800	-0.0003	-0.0000	0.0003

Figure 3. RMS Error Value of Landsat Image 8.

The RMS error value on Sentinel 2 image is 0.0012

	Map X	Map Y	Image X	Image Y	Predict X	Predict Y	Error X	Error Y	RMS
#1+	195485.00	9108268.00	3989.51	3072.57	3989.5925	3072.5964	0.0825	0.0264	0.0867
#2+	193457.00	9110910.00	3790.67	2805.08	3790.5575	2805.0440	-0.1125	-0.0360	0.1181
#3+	192943.00	9103666.00	3728.69	3529.40	3728.6008	3529.3714	-0.0892	-0.0286	0.0937
#4+	191648.00	9107350.00	3604.29	3158.60	3604.4104	3158.6385	0.1204	0.0385	0.1264
#5+	189602.00	9110741.00	3404.75	2816.48	3404.7488	2816.4796	-0.0012	-0.0004	0.0012

Figure 4. RMS Error Value Sentinel Image 2

3.3. Image Processing for Surface Temperatures

The following is the result of surface temperature processing on the thermal band 10 on the three Landsat 8 imageries of 19 January 2016, 26 May 2016 and 30 August 2016.

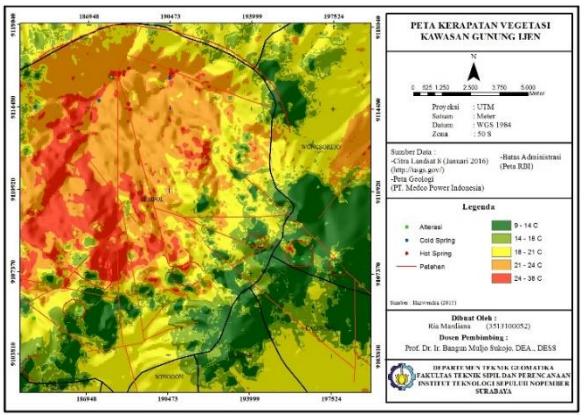

Figure 5. Image Processing Results of Land Surface Temperature January

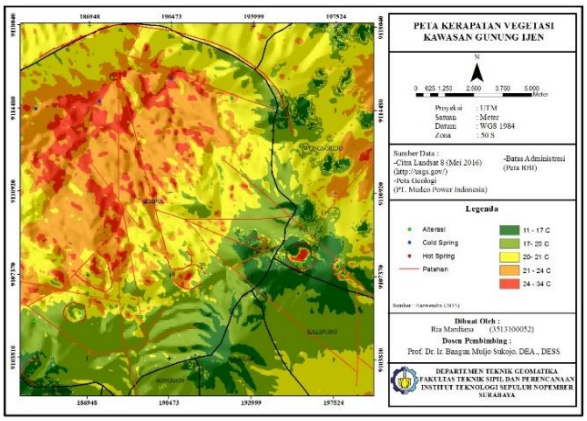

Figure 6. Image Processing Results of Land Surface Temperature May

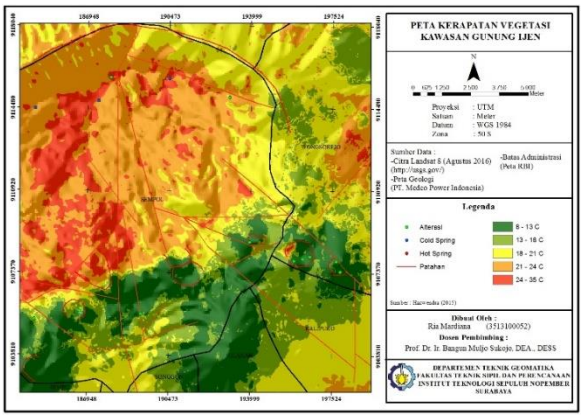

Figure 7. Image Processing Results of Land Surface Temperatures August

The Ijen mountain area has a surface temperature of 21 ° C - 34 ° C [3]. For the result of surface temperature of soil at data processing yield the lowest temperature that is 8 ^{o}C and highest temperature 38^{o}C. The higher the ground surface temperature of an area, the higher the potential for geothermal in the area [14]. Here is a table of minimum and maximum temperature on surface temperature data processing using Landsat image 8.

Table 1. Surface Temperature

Month	Low Temperature	High Temperature
January	9 ° C	38 ° C
May	11° C	34 ° C
August	8° C	35 ° C

The results of all three thermal bands have differences. In January is a wet month so it can detect higher temperatures higher than in May and August, this is because in wet months the water content in the soil surface more so as to absorb more sunlight [6].

3.4. Land Elevation

The results of processing for altitude of land based on the class height of land as follows:

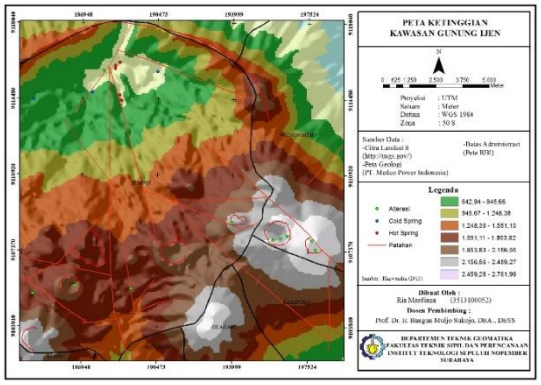

Figure 8. Map of Land Elevation

Then tested the correlation between elevation and ground surface temperature. Correlation analysis aims to determine the relationship between two or more variables. In this research, correlation analysis is used to find out the correlation of surface temperature with altitude. The following is the result of correlation of surface temperature with the height that will be displayed in the table

Table 2. Surface and Land elevation Correlation Results

Month	Residu
January	-0,89
May	-0,86
August	-0,82

The result of land elevation correlation and surface temperature can be seen that the correlation between height and surface temperature has a very strong relationship with the best correlation that is the correlation of height and surface temperature of January is -0.89. The relationship between altitude and surface temperature is negative due to their unrelated relationship. The higher the land, the lower surface temperature will be lower [9]

3.5. Land Cover

In this study the classes specified are shrubs, vacant land / grass, plantations, forests, settlements and craters. For accuracy of land cover processing is calculated using confusion matrix method, where the tolerance limit given is ≥ 80% [7].

Here is a land cover map of data processing:

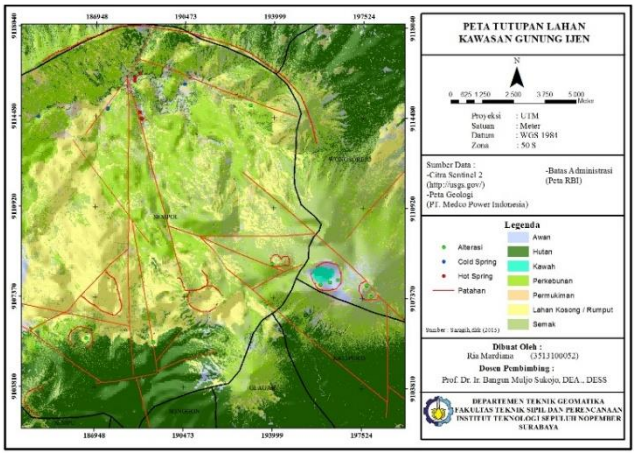

Figure 9. Map of land cover

To perform the accuracy test, it takes ground truth data as sample data taken from the location of sample points by 30 sample points. The result of the confusion matrix calculation is 80%. If the land cover is dominated by trees, the smaller the geothermal potential in the area [10]. The following is the area of each land cover.

Table 3. Results of Land Cover

No	Land Cover	Luas (ha)	%
1	Farm	6621,4923	21,72
2	Forest	10711,301	35,13
3	Copse	6896,3687	22,62
4	Grass	5744,9547	18,84
5	Crater	42,962237	0,14
6	Settlement	464,89779	1,52

Land cover in the research area is dominated by forests by 35% of the research area.

3.6. Vegetation Index

The value of vegetation index is one indicator to determine the level of drought or greenness in an area. The band channel in this study can be from band 4 and band 5 from Landsat 8 image whereas for image Sentinel 2 use band 4 and band 8 by using NDVI algorithm (Normalized Difference Vegetation Index). The following is the result of the processing of vegetation density on Landsat 8:

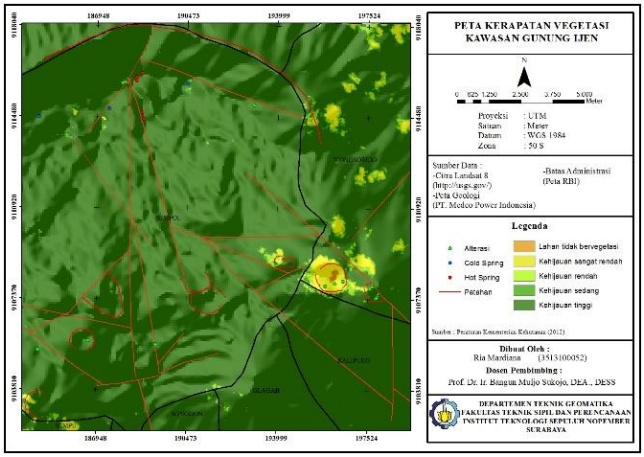

Figure 10. Maps of Vegetation Spread Using Landsat Image 8

The following is the result of the processing of vegetation density on Sentinel 2 image:

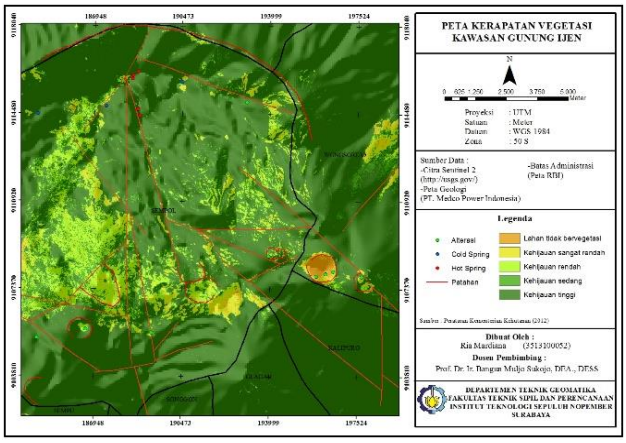

Figure 11. Maps of Vegetation Spread Using Sentinel Image 2

From the results of processing vegetation index in the area of Mount Ijen there are 5 classification of index level in the area of Mount Ijen. In Landsat 8 imagery, most of the research area is dominated by high greenish-ness and clouds are also defined with very low greenish density.

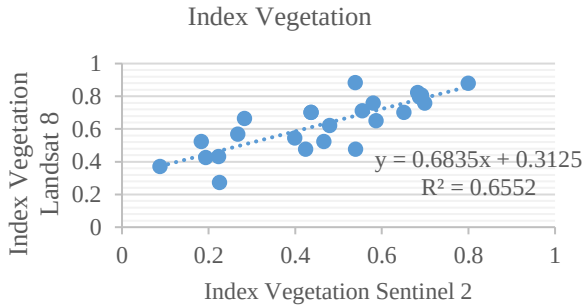

Figure 12. Correlation of vegetation index

From result of correlation of Landsat 8 and Sentinel 2 image vegetation density obtained residue equal to 0,80. This shows the correlation of the two relationships is very strong [10]. The higher the value of vegetation density, the lower the geothermal potential of the area [9].

3.7. Analysis of Geothermal Potential

After all parameters in the determination of the geothermal potential area is processed then the entire parameter area is overlaid so that it produces a new area that is the geothermal potential area in the area of Mount Ijen as follows:

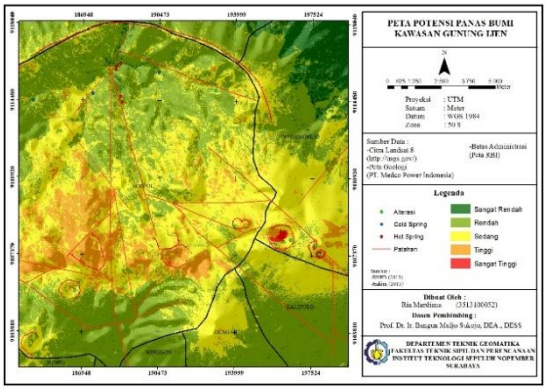

Figure 13. Geothermal Potential Map

Based on the results of classification on data processing in the area of Mount Ijen, then obtained the area of each class. The following is a table of geothermal potential in the area of Mount Ijen.

Table 4. Area of Geothermal Potential

	Area (Ha)	%
Very low	2017,31	6,23
Low	15724,19	48,62
Medium	10918,9	33,76
High	3638,02	11,25
Very High	39,43	0,12

The identified areas have very high geothermal potentials located on Mount Ijen located in Wongsorejo Subdistrict. The area has a high surface temperature on a high surface. Besides it has low vegetation index value and is in land cover in the form of grass, crater, settlement and copse.

4. Conclusions and suggestions

4.1. Conclusion

Based on the results of this final project, it can be concluded as follows:

1. Based on satellite image processing can be concluded:
   - Surface temperatures in the area of Mount Ijen have anomalies with large temperatures ranging between 18° C to 38° C. With the correlation between surface temperature and altitude for each thermal band on Landsat 8 image produces a very close relationship with the highest value of -0.89.
   - The correlation of Landsat 8 and Sentinel 2 image vegetation densities is very strong with a residual value of 0.81.
   - The land cover confidence matrix receives a value of 80%. Land cover in the research area is dominated by forests by 35% of the research area
2. There is a potential area of geothermal potential is very high on Mount Ijen with an area of 39.43 hectares located in Wongsorejo sub-district and adjacent to District Sempol.

4.2. Suggestion

The advice given from the results of this study are as follows:

1. We recommend using Landsat imagery that is a bit cloud because the sensor is not able to penetrate the cloud and can affect the results on the classification of vegetation density and temperature processing.
2. To generate the geothermal potential, further geophysical, geochemical and geological studies on geothermal potential points are required.

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