Identification of Geothermal Environments by Using Landsat Imagery at PLTP Sarulla unit I, Pahae Jae Subdistrict, North Tapanuli

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Identification of Geothermal Environments by Using Landsat Imagery at PLTP Sarulla unit I, Pahae Jae Subdistrict, North Tapanuli

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Abstract. Geothermal energy sources have a significant influence on renewable energy sources as an affordable and sustainable solution. The aim of this study was to identify geothermal sources at the Sarulla PLTP using remote sensing technology. The method of this study includes field surveys by obtaining hotspots and temperature values in geothermal sources, and identification of geothermal sources is determined by mapping of land use change (NDVI) and heat source distribution (LST). The results show vegetation area has been changed from 0,6 to 0,3, and the temperature value is increasing 25 °C to 28 °C in 2010 to 2018 over PLTP Sarulla. Negative correlation found between NDVI and LST. Surface changing over geothermal resources as an evidence of environment changes. The geothermal sources increase with the opening of land in the PLTP Sarulla. So the results of this study can be recommended to the public and the government.

1. Introduction

Indonesia's energy consumption is one of largest country in the world. Geothermal energy power can be one of the solution of energy generation. Based on the data by Ministry of Energy and Mineral Resources projects that Indonesia will be the largest electricity producer of geothermal power and defeats United States and Philippines in 2021 [1] [2]. PLTP PT. Sarulla is located in Pahae Jae Subdistrict, North Tapanuli District, North Sumatera, Indonesia that has three units which is developed in two locations. First, unit I, capacity project namely the Silangkitang (SIL). Second, units II and III, namely the Namora - I - Langit (NIL) project with a large capacity of 110 MW. PLTP Sarulla has a potential observing of geothermal resources.

Remote Sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data obtained with a device without direct contact with objects, or the phenomena studied [3]. Application of this technique in geothermal energy exploration field can be used to identify the surface type and the temperature level condition in the study area. Surface type identify by using vegetation index (NDVI), which is solar radiation development to signal processing of digital data from brightness values of several satellite sensor channels [4]. For temperature, land surface temperature (LST) is used to indicate the distribution of geothermal resources [5].

Remote sensing techniques have previously been used in research, such as research [6] concerning geothermal identification with geographic information systems and geothermal remote sensing in Dolok Merawa District, where the minimum land surface temperature (LST) is 2.720490 ° C and maximum value is 37.889587 °C. ENVI 4.7 and ArcGIS 10 was applied as a tool for calculating NDVI and LST. Based on the previous study, researchers are interested to observe the changes of land area and temperature levels in geothermal areas of PLTP Sarulla, North Tapanuli Regency by using satellite imagery.

2. Research Method

2.1 Research Time and Location

Geographically, Karo Regency is located between 2° 20' - 2° 41' North Latitude and 98° 05' - 99° 16' East Longitude with an area of 3.800,31 km. It is classified as flat (3.16 percent), gentle slope (26.86 percent), skewed (25.63 percent) and steep (44.35 percent). This field survey was conducted on 23^{rd} April 2018 to 25^{th} April 2018. On the other hand, the time series of datasets start from 2010 to 2018.

2.2 Tool and Material

GPS (Global Position Systems) DNS GARMIN and thermometer was used for field surveying, and ArcGIS 10.0 and ENVI 4.7 to analysis processing. This study was collected by the Landsat 8 OLI Satellite Image (http://glovis.usgs.gov/) as datasets from 2010 to 2018, earth map of North Sumatera (http://www.bakosurtanal.go.id/peta-rupabumi/), and administration map of North Tapanuli Regency.

2.3 Analysis Data

First, we do pre-processing of Landsat 8 OLI raw data to improve the data quality by using the geometric correction and radiometric correction. Vegetation indices are used for monitoring vegetation condition and land cover changes. The normalized difference vegetation index is an index of "greenness" that generated of red reflectance and near infrared reflectance of solar radiation to surface condition with interval range index (-1 to 1) that negative 1 refers to less area indices and positive 1 refers to more greenness. The formula of the radiometric correction considers

$$L_\lambda = \left(\frac{L_{\max} - L_{\min}}{QCAL_{\max} - QCAL_{\min}} \right) \times \left(Q_{cal} - QCAL_{\min} \right) + L_{\min}$$

Where L_λ is radiometric correction index, $L_{\max}$ is the maximum value of digital number each band, and $L_{\min}$ is the minimum value of digital number each band, $QCAL$ is the index value of each band, $QCAL_{\max}$ is the maximum value of pixel number value each band (i.e. 65535 for all band) , $QCAL_{\min}$ is the minimum value of pixel number value each band (i.e. 1 for all band).

NDVI can be calculated by using

$$NDVI = \frac{R_{NIR} - R_R}{R_{NIR} + R_R}$$

Where NDVI is normalized difference vegetation index, R_{NIR} is red reflectance, and R_R is near infrared reflectance.

For temperature, we do the calculating by using band infrared of Landsat 8 OLI, band 10.

$$TI = \left(\frac{K_2}{In\left(\frac{K_1}{L_\lambda} + 1 \right)} \right)$$

Where TI is temperature index, K_1 is Constanta 1 (774.89), and K_2 is Constanta 2 (1321.08)

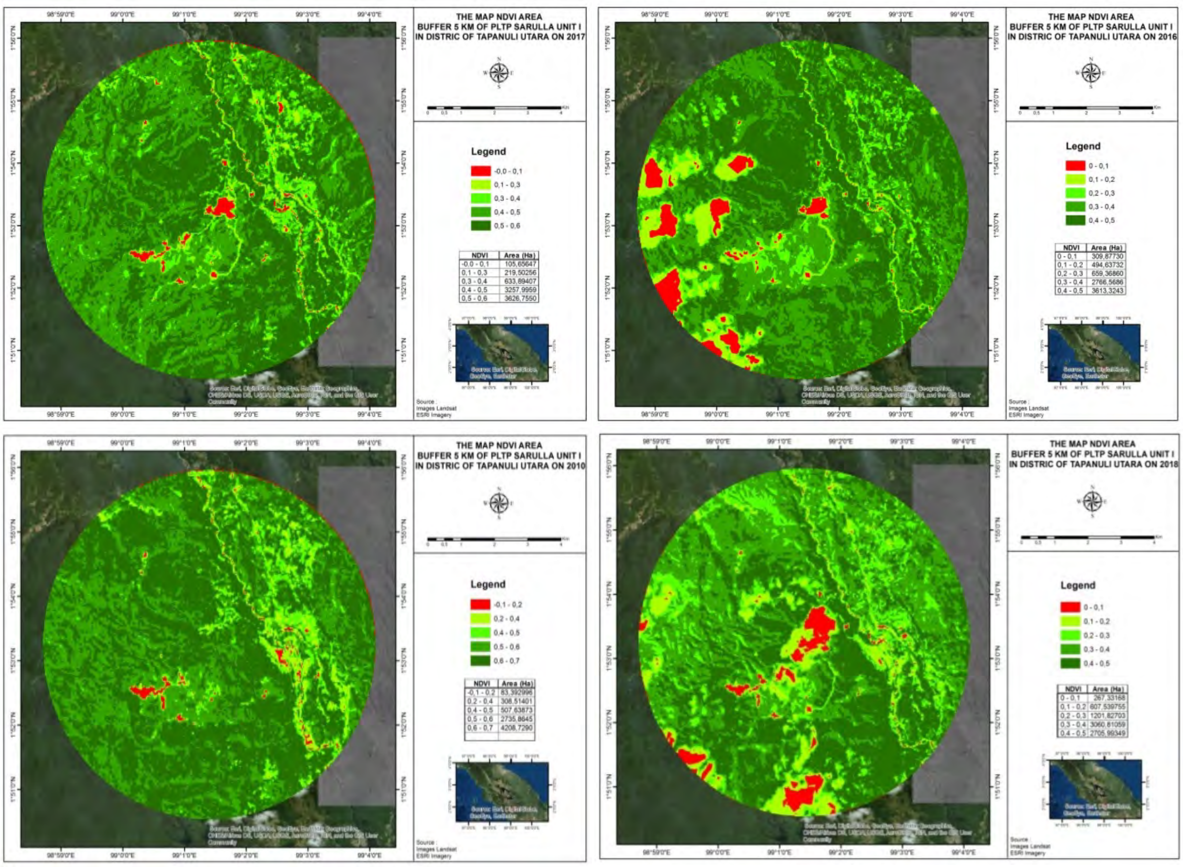
3. Result and Discussion

This research focus on the environment change around geothermal resources in PLTP Sarulla follows the changes in land cover area and temperature by using Landsat 8 OLI imagery. Field survey is in a reference point for data processing, while Band satellite image data was 1 to 11 USGS sources, to display a surface image on Landsat 8 OLI, true color from RGB to 4.3, 2 where R = Band 4 (Red), G = Band 3 (Green) and B = Band 2 (Blue). On Landsat 8 OLI Digital Number that is 16 bits, 2^{16} = 65,356 minimum price = 0 (Black) and maximum price = 65,355 (White). Image and true color image is on Landsat 8 OLI.

3.1 Vegetation Index

Vegetation index by affecting NDVI values calculates in the PLTP Sarulla from 2010 to 2018 can be seen in Figure1.a, 1.b, 1.c and 1.d below. NDVI result of Landsat 8 OLI overlayed above the google earth, caused by match field survey with Landsat 8 OLI image. Circle area as mask area of the main hotspot of PLTP Sarulla with the radius area more than 100 meter.

(a) (c)



(b) (d)

Figure 1. Spatial map of NDVI from Landsat 8 OLI for: (a) 2010, (b) 2016, (c) 2017, and (d) 2018. Red color represents NDVI value from 0 to 0.1 indicates less vegetation, dark green represent more greenness of NDVI .

The picture above shows that the NDVI value has decreased very dramatically and it is very clearly seen a decrease as in the values representing vegetation in the range of 0.1 to 0.7. NDVI classification is divided into three parts, namely in the range <0.2 categorized as open land, water, and not vegetated while in the range 0.2 - 0.5 it is categorized as low vegetation and in the range> 0.5 categorized as high vegetation area. It can be seen in NDVI calculations picture in 2010, 2014, 2016, 2017 and 2018 in the Sarulla PLTP area that each year the vegetation density has decreased quite significantly as we can see in table 3.1 below.

Table 1. ***NDVI Change in*** **PLTP Sarulla Area in 2010, 2014, 2016, 2017 and 2018**

	2010	2014	2016	2017	2018
NDVI **min**	0.5	0.3	0.1	-0.1	0.1
NDVI max	0.7	0.5	0.5	0.6	0.5
Average	0.6	0.4	0.3	0.25	0.3

From the data in table 4.6, we can graph the average temperature changes in the Sarulla PLTP above. Figure 2 below shows a graph of average temperature changes in Sarulla Unit I PLTP from 2010 to 2018.

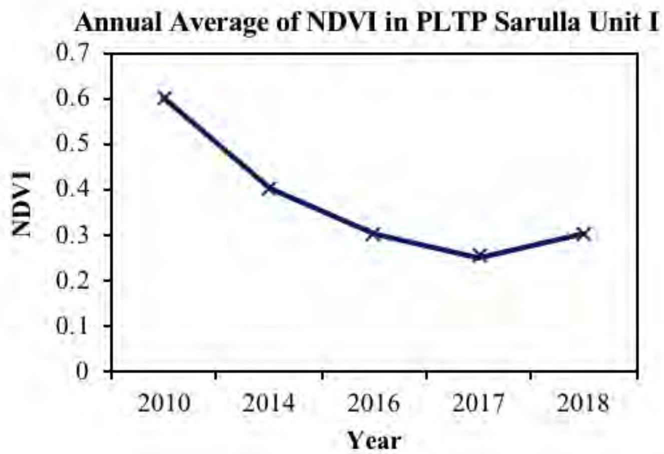
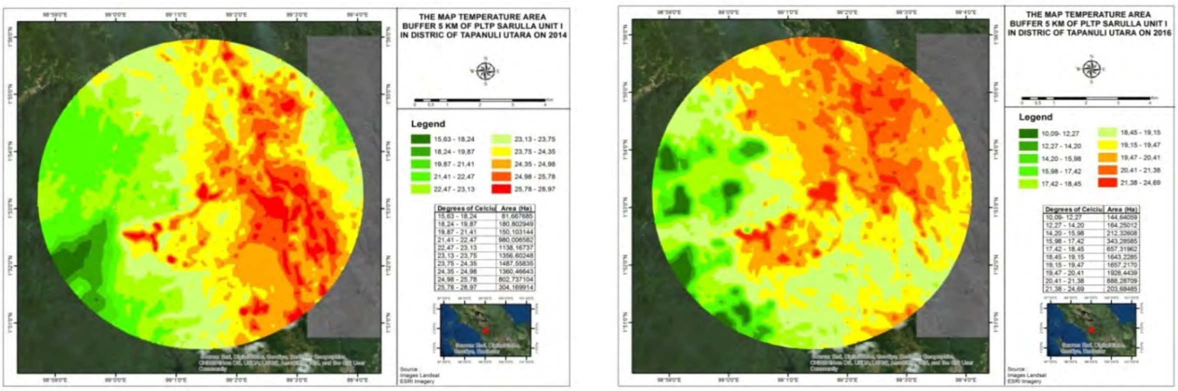


Figure 2. Graph of Average Change in NDVI at PLTP Sarulla Unit I

From Figure 2. above, it shows a graph of average change in NDVI value at PLTP Sarulla from 2010 to 2018. Where the highest NDVI average value was in 2010 amounted to 0.6 and the lowest NDVI average value was in 2017 at 0.25 which can be caused by the Sinabung Mountain eruption so that it affects the vegetation condition of the Sarulla PLTP area which is exposed to volcanic ash from the volcanic eruption.

3.2 Temperature Index

For temperature index contour maps in the PLTP Sarulla area from 2010-2018 can be seen in Figure 3.a, 2.b below.



(a) (b)

Figure 3. Spatial map of LST from Landsat 8 OLI for: (a) 2014 and (b) 2016. Red color represents high temperature, dark green represent low temperature.

The picture above shows that LST values had a very drastic decline and very clearly seen a drastic increase, from temperature data from 2010, 2014, 2016, 2017 and 2018 that have been obtained, it can be made - the average of temperature changes condition that occur in the PLTP Sarulla Unit I area which can be seen in table 2 below. Nishar et al. in 2016 applied unmanned aerial vehicle (UAV) to observe geothermal environments in Wairakei – Tauhara geothermal field by thermal infrared imaging. Their result described that any potential of thermal infrared to monitoring the geothermal environments [7].

Table 2. Average Temperature Change at PLTP Sarulla Unit I Area In 2010, 2014, 2016, 2017 and 2018

	2010	2014	2016	2017	2018
***TI* min**	23.11	24.35	19.47	29.27	17.06
***TI* max**	28.01	28.97	24.69	33.44	20.91
Average	25.56	26.66	22.08	31.35	18.98

From the data in table 3.2, we get the graph of averages in temperature changes in PLTP Sarulla from 2010, 2014, 2016, 2017 and 2018. Figure 4 shows a graph of the average temperature change in PLTP Sarulla Unit I from 2010 to 2018.

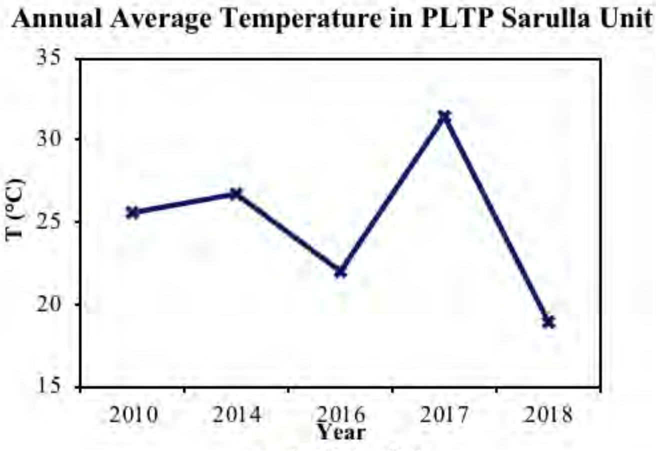


Figure 4. Graph of Average Temperature Change at PLTP Sarulla Unit I

Based on the index map of temperature at Sarulla Unit I PLTP, the highest temperature is represented by red and the lowest temperature is shown in green. It can be seen in 2017 that the area around PLTP Sarulla Unit I had the highest temperature reaching 31,35^0 C compared to other years and the lowest temperature was in 2016 at 22,08^{0}C.

3.3 *Graph of Relationship between NDVI and LST*

3 represents the values of NDVI from 2010, 2014, 2016, 2017 to 2018 decreased, while the LST values from 2010, 2014, 2016, 2017 and 2018 increased. The relationship between NDVI and LST shows can be seen in table 3. The relationship between vegetation indices and temperature indices has potential challenges in the changes in geothermal environment.

Table 3. NDVI and LST Value in 2010, 2014, 2016, 2017 and 2018

Year	NDVI	LST
2010	0,6	25,56
2014	0,4	26,66
2016	0,3	22,08
2017	0.25	33,44
2018	0.3	18,98

The values of NDVI and LST can be seen in table 3. Decreasing NDVI value means a decrease in the level of vegetation density which causes an increase in temperature (LST) at PLTP Sarulla area. This is obtained from 30 observation points which can be seen in the graph of NDVI and LST relationships. R value represent the correlation coefficient value that has range between +1 to -1. Overall, correlation coefficient shows the positive correlation inThe graph of the relationship between NDVI and LST from 2010 to 2018 can be seen in Figures below.

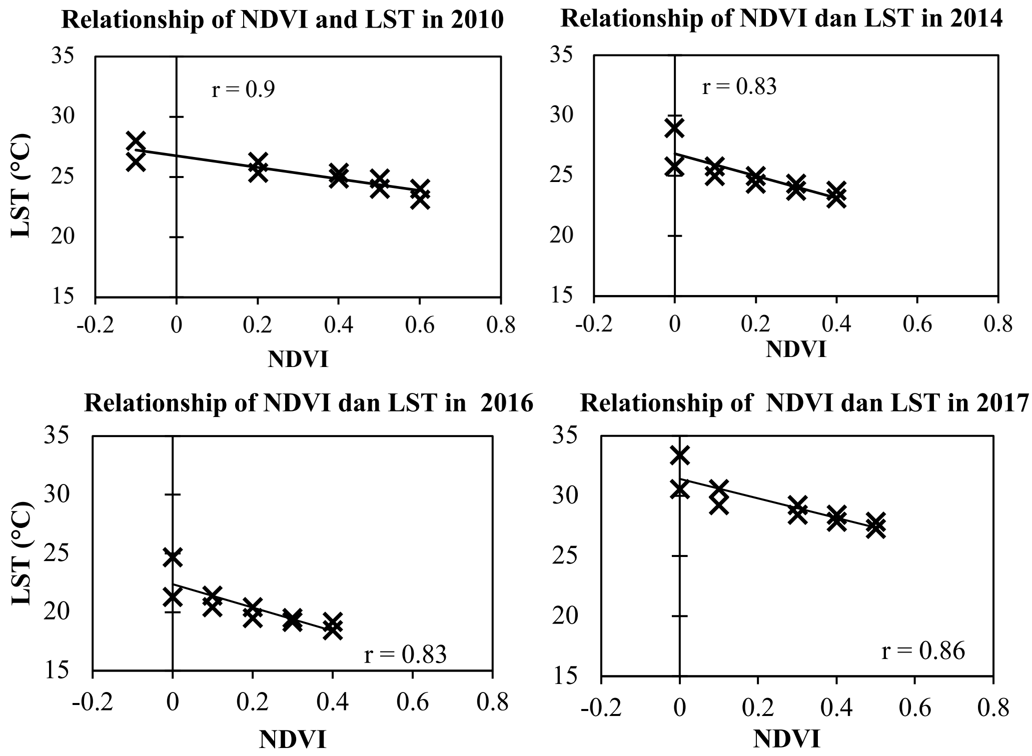


Figure 5. Relationship between NDVI and LST: (a) 2010, (b) 2014, (c) 2016, and (d) 2017 in PLTP Sarulla Unit I

From the pictures above, it can be seen for NDVI with the range from 0 - 0.1 temperature in the range 24°C - 30°C and for NDVI with a range of 0.4 - 0.5 temperature in the range 23°C - 24°C. This proves that the lower the NDVI value, the higher the temperature value, on the contrary if the NDVI value is higher the lower the temperature value [8]. The characteristics of NDVI value indicates the plant biodiversity, succession process and also phenology [9]. In field survey support the statement that more land discovers of vegetation, the surface temperature become higher.

3.4 Discussion

Based on the image map 1.a, 1.b, 1.c, and 1.d, the NDVI map shows a decrease in the green level around the PLTP Sarulla, and the temperature values in Figure 2.a, 2.b, 2.c and 2.d are seen increasing and it can be said that the PLTP Sarulla geothermal power plant area had very significant environmental changes. From all the pictures and tables, it has been proven that there has been an environmental change that allows humans to be disturbed in farming in that area.

4. Conclusion

When the NDVI decline is very drastic and the temperature increases, it can be concluded that environmental changes occur at these locations in the degraded land category. The environmental changes / land damage can interfere with humans who are around the area in farming and living [10].

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