GROUND SURFACE CHANGES DETECTION AT GEOTHERMAL SURFACE MANIFESTATIONS USING MULTI-TEMPORAL LANDSAT IMAGERIES

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ABSTRACT: Remote sensing technologies are often used for various purposes, such as geothermal exploration and hazard mitigation. Detecting surface temperature anomaly to find the potential of geothermal energy are commonly used as the initial survey in exploration activities. In this study we discussed about the application of remote sensing technology for change detections of reflectance at surface manifestation of geothermal systems. The change detections of surface reflectance are targeted to the change of clay minerals due to hydrothermal alteration. We extracted the temporal changes of surface reflectance of Landsat data from 1996 to 2014. We observed how reflectance value of surface manifestation has changed during 18 years. In addition, we extracted land surface temperatures at each surface manifestation to know relation between temperatures and reflectance changes. Mt. Patuha in West Java, Indonesia was selected as study site due to existences of 15 surface manifestations. The changes of surface reflectance are detected based on series of Landsat imageries at 15 surface manifestation points. We found that surface reflectance has changed at surface manifestation. The highest reflectance values were occurred mostly on 2013 and the lowest values on 1996. To validate the result, we selected 6 zones out from surface manifestations that predicted as stable reflectance values over time. The reflectance showed only small changes over time with rms about 0.021, it may imply that the change of spectral reflectance at surface manifestation is related to surface condition rather that environmental effects. The changes of surface reflectance might be related to the surface changed which is controlled by subsurface condition. Therefore, this study could be used to understand the characteristics of the subsurface condition such as structure and/or reservoir.

1. INTRODUCTION

According to Gupta and Roy (2007), the world's population is increasing annually. This population growth led to an increase in various aspects, one of them in energy consumption. There are more or less the increases in energy consumption by 50% during the years 1980-2003, which is caused by the increase of as much as 42% growth in population around the world, especially in developing countries. The increase in population and increase in income causes a change in the pattern of life. From this it can be estimated energy demand will increase by 57% by 2025. There are about 63% of total energy consumption comes from fossil fuels like coal, oil and natural gas. World demand for oil is expected to rise from 78 million barrels in 2002 to 103 million barrels in 2015 and 119 million barrels per day in 2025, but this kind of energy is not renewable.Therefore, it is an important task to develop alternative and sustainable energy such as geothermal energy. We study about geothermal using remote sensing technology. We observed how the surface manifestations could change over time in view point of soil composition and/or altered minerals. The optical remote sensing data is used in this study because the sensor was proved effective to detect altered rocks at volcanic terrain (Saepuloh et al, 2010). According to Browne and Allis (1970), alteration minerals may change due to several factors, such as temperature, pressure, permeability, chemical composition of rocks, geothermal fluid, and duration of the geothermal exploitation. In addition, surface manifestations are a dynamic surface features that represent interacting subterranean systems of water, heat, and rocks (Heasler et al., 2009). This research is crucial to understand the nature characteristics of geothermal reservoirs based on remotely sensed data (Lagat, 2009).

2. DATA AND METHODOLOGY

2.1 Data

Multi-temporal Landsat imagery data used in this research are collected freely from 1996 to 2014 through USGS website: *http://earthexplorer.usgs.gov*. The data are listed in **Table 1**. There were some gaps in the series of acquisition time because of Landsat 7 optical sensor's error after 2003. Therefore we collected only 10 data without stripping for data processing.

Table 1 List of data used in the research

No	Path/Row	Sensor	Date
1	122/65	Landsat 5	25-Jul-96
2	122/65	Landsat 5	14-Sep-97
3	122/65	Landsat 5	19-Aug-99
4	122/65	Landsat 7	1-Sep-01
5	122/65	Landsat 7	18-Jul-02
6	122/65	Landsat 7	18-May-03
7	122/65	Landsat 5	2-Jul-05
8	122/65	Landsat 5	18-May-06
9	122/65	Landsat 8	10-Sep-13
10	122/65	Landsat 8	17-Feb-14

Figure 1 Location of study area at Mount Patuha, West Java

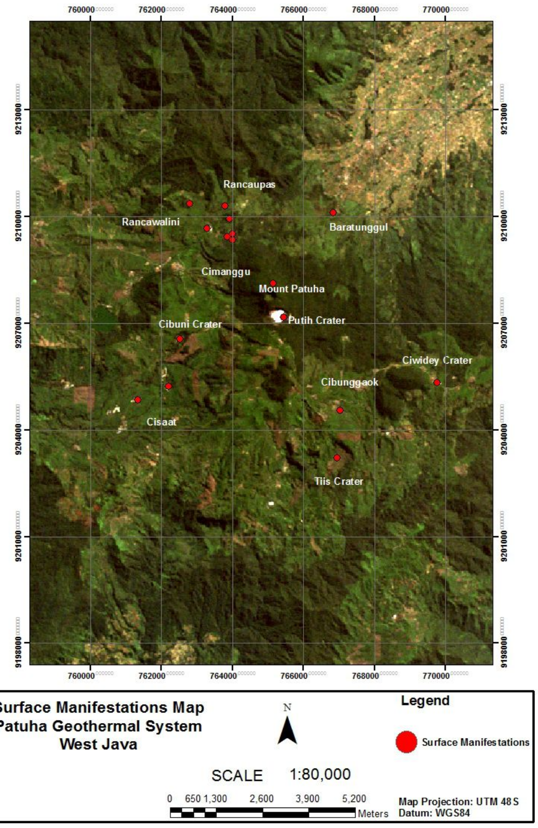

Figure 2 Location of 15 surface manifestations presented by green dots overlaid on color composite of Landsat-8 for R,G,B=Band Red, Green, and Blue (True Color)

This research took place at Mount Patuha, that located 200 km from Jakarta or 46 km from Bandung, the map showed on **Figure 1**. Patuha geothermal system t is a vapor dominated geothermal system with 4 type of manifestation: Crater lake, Fumarole, Hot spring, and Mudpots (Schotanus, 2013). This system has formation of low permeability barrier can be due to the deposition of silica as a result of cooling of reservoir fluids in the shallower parts of the system or by the deposition of calcite, gypsum or anhydritedue to the heating (and vaporization) of recharge waters. However, the presence of this barrier can also be related to the process of argillization, where certain minerals are converted into clay minerals due to hydrothermal alteration, or to the geological structure and lithologic contrast (Ingebritsen and Sorey, 1988). In **Figure 2,** it showed the coordinate from each manifestation that obtained from previous research by Schotanus (2013). This map showed the position from each manifestation.

2.2 Methodology

In this research we conducted 3 steps processing to obtain the result First step is to conduct georeferencing and atmospheric correction on the imaging data of Mt. Patuha in order to establish a geographic coordinate system and remove the effect of water vapor in the atmosphere. We did radiometric or atmospheric correction and geometric correction. In radiometric correction, FLAASH model become our choice, this model fit the needs of the research for reflectance extraction because it is able to correct the digital number of Visible Light wavelength to Near Infrared (Bernstein et al., 2006). For thermal band, in this research atmospheric correction used to approximate and remove the atmospheric contributions from thermal infrared radiance with the model that this algorithm assumes that the atmosphere is uniform over the data scene and that a near-blackbody surface exists within the scene, the location of the blackbody surface is not required for this correction, a single layer approximation of the atmosphere is used, no reflected downwelling radiance is also assumed data (Johnson and Young, 1998). While the geometric correction, RMS error for Landsat TM should be less than 1.2 per pixel (Kardoulas et al., 1996). In **Figure 3**, the results of the calculation are displayed RMSe graphs, there was no RMSE values that exceeding 1.2, so all of this imagery already have good geometric quality.

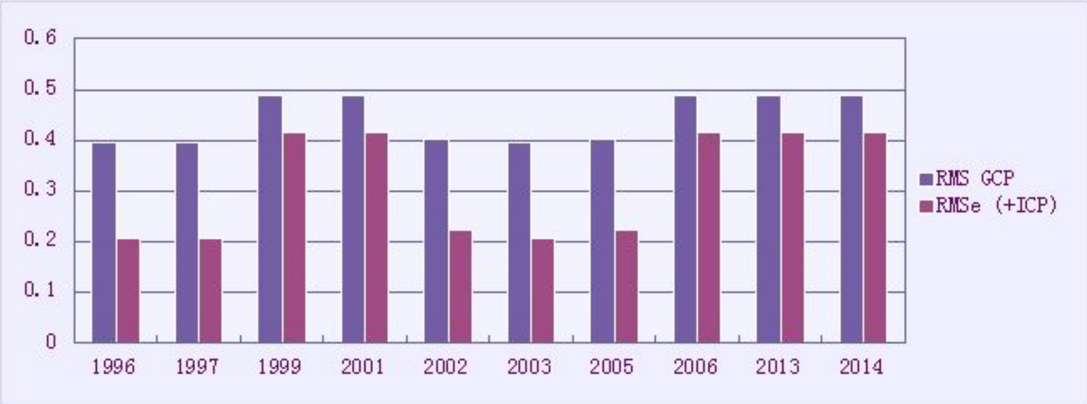

Figure 3 Chart of RMS Error from geometric correction of Landsat imageries data

Secondly is we extracted spectral reflectance from all of surface manifestations. We observed how this reflectance values changes from each band during 18 years from 10 imagery data. To validate these changes, we need data that we predicted as stable reflectance over time. According to Syren (1996), if there were no natural events such as forest fire or storm felling or forest management activities as thinning and cleaning-cutting, the reflectance of vegetation at forest are stable over time. On another research, according to Duong (1997), if the land cover did not change to another type, the spectral reflectance pattern should be stable. So we used reflectance data from vegetation and bare land, with 3 samples each type. From statistical process, we got representative values of reflectance from each band that we considered as the stable values. From this values we could validate, if there were changes from each band which the changes are exceed this values, we can concluded that the changes were happened. In addition, we did land surface temperature data extraction from each surface manifestation points, detecting surface temperature can be indicators to the availability of geothermal surface manifestation (Siahaan, 2011). This data also used to know relation between temperature and reflectance changes. After the reflectance changes have been detected, we made analysis how this changes happened depend on spectral and temperature analysis.

3. SPECTRAL REFLECTANCE ANALYSIS

Spectral reflectance, [ρ(λ)], is the ratio of reflected energy to incident energy as a function of wavelength. Various materials of the earth's surface have different spectral reflectance characteristics. Spectral reflectance is responsible for the color or tone in a photographic image of an object. Trees appear green because they reflect more of the green wavelength. The values of the spectral reflectance of objects averaged over different, well-defined wavelength intervals comprise the spectral signature of the objects or features by which they can be distinguished. To obtain the necessary ground truth for the interpretation of multispectral imagery, the spectral characteristics of various natural objects have been extensively measured and recorded. The spectral reflectance is dependent on wavelength, it has different values at different wavelengths for a given terrain feature (Aggarwal, 2003). In **Figure 4** shows an example of the spectral pattern that formed at the surface manifestations. From 1996 to 2014 show there were no changes in spectral pattern, but the reflectance values were always changes each year.

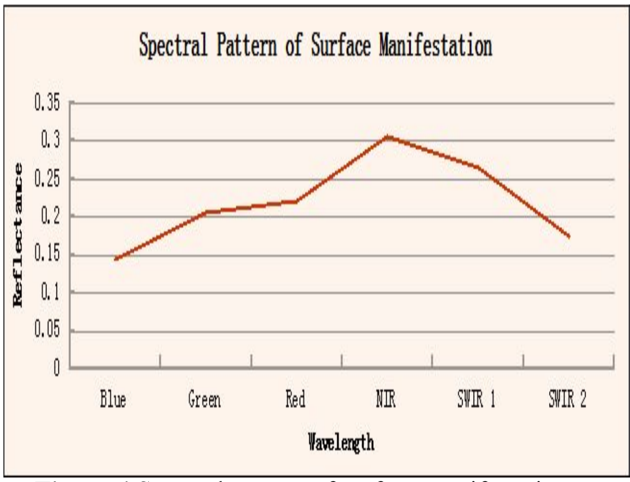

Figure 4 Spectral pattern of surface manifestation at Putih Crater

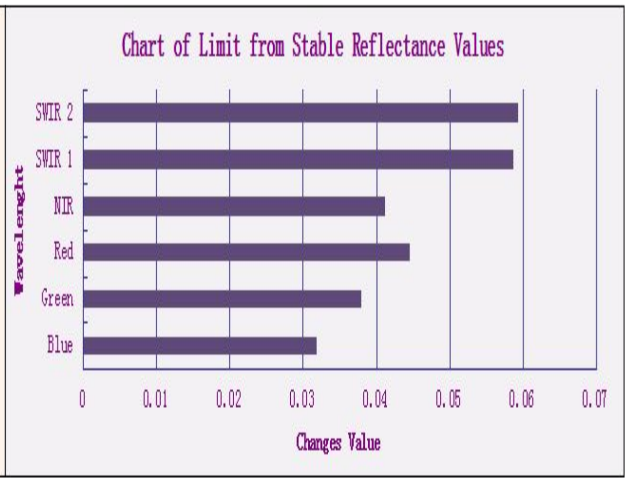

Figure 5 Chart of limit from stable changes values

These changes must be validated with representative stable values from each band that appear on **Figure 5**, the changes were happened if there were changes from each band at every surface manifestation which the changes are exceed this values. The reflectance showed only small changes over time with RMS about 0.021, it may imply that the change of spectral reflectance at surface manifestation is related to surface condition rather that environmental effects. After validated reflectance values from ground surface manifestations, we could get information about the changes values on **Table 2**. From these reflectance changes, it concluded that there were reflectance changes that happened on surface manifestations that related to clay minerals as results of hydrothermal alteration that become the main contents of the surface manifestations. But because of this research without did ground truth survey, we could not detected chemical reactions changes of altered mineral that occurred at subsurface manifestations.

Table 2 List of changes information

Manifestation Name	Reflectance Value (Year)		Changes Value
	Minimum	Maximum	
Baratunggul	1996	2013	0.0348
Cibunggaok	2002	2006	0.0367
Cibuni Crater	1997	2013	0.0491
Cimangguk 1	1996	2013	0.0397
Cimangguk 2	1996	2013	0.0252
Cimangguk 3	1996	2013	0.0221
Cimangguk 4	1996	2013	0.0207
Cisaat 1	1996	2002	0.0585
Cisaat 2	1999	2002	0.0873
Ciwidey Crater	2001	1997	0.0891
Putih	1996	2006	0.055
Tiis Crater	1996	1999	0.0275
Rancaupas	2005	2013	0.0319
Rancawalini 1	1996	2013	0.0275
Rancawalini 2	1996	2013	0.0253

From **Table 2**, there were information about when each surface manifestation has lowest and highest value on mean of its reflectance value from all bands, and also there are changes values that counted from highest value reduced by lowest value of reflectance that occur over 18 years. From this information we got that in this geothermal system, almost from every surface manifestations have highest reflectance values on 2013 and lowest value on 1996. Using normal distribution on statistical operation, it appears on **Figure 6**. Area that made between **Green Line** and **Red Line** showed normal distribution values, there are 2 reflectance changes from surface manifestations that become anomaly because they exceed the **Red Line.**

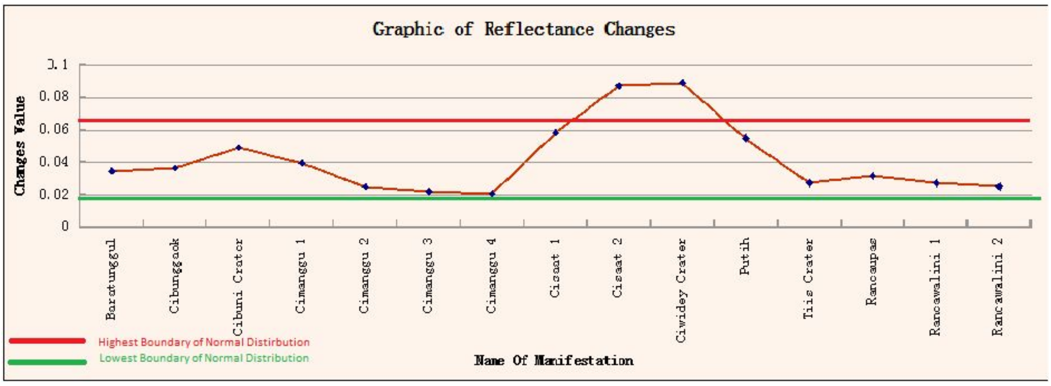

Figure 6 Graphic of mean from all band's reflectance changes values

4. LAND SURFACE TEMPERATURE ANALYSIS

According to Johnson and Young (1998), due to the atmospheric correction for thermal band that used in this research, this process needed 2 thermal band from each year, so we only could use data from Landsat 7 (band 6H and 6L) and Landsat 8 (band 10 and 11). Because the emissivity of an object affects how much energy an object emits, emissivity also influences a thermal imager's temperature calculation. Consider the case of two objects at the same temperature, one having high emissivity and the other low. Even though the two objects have the same temperature, the one with the low emissivity will radiate less energy. Consequently, the temperature calculated by the thermal imager will be lower than that calculated for the high emissivity object. To separate the effect of the emissivity of the object to get the actual temperature, one of the method that used is Emissivity Reference Channel, this techniques assume that all the pixels in one band from thermal infrared data has a constant emissivity. Using this constant emissivity, temperature and the calculated temperature is used to calculate the emissivity values in all the other bands using the Planck function (Kealy et al, 1993). Temperature values of the object that free from object emissivity effects as shown by **Figure 7** (on °Celsius).

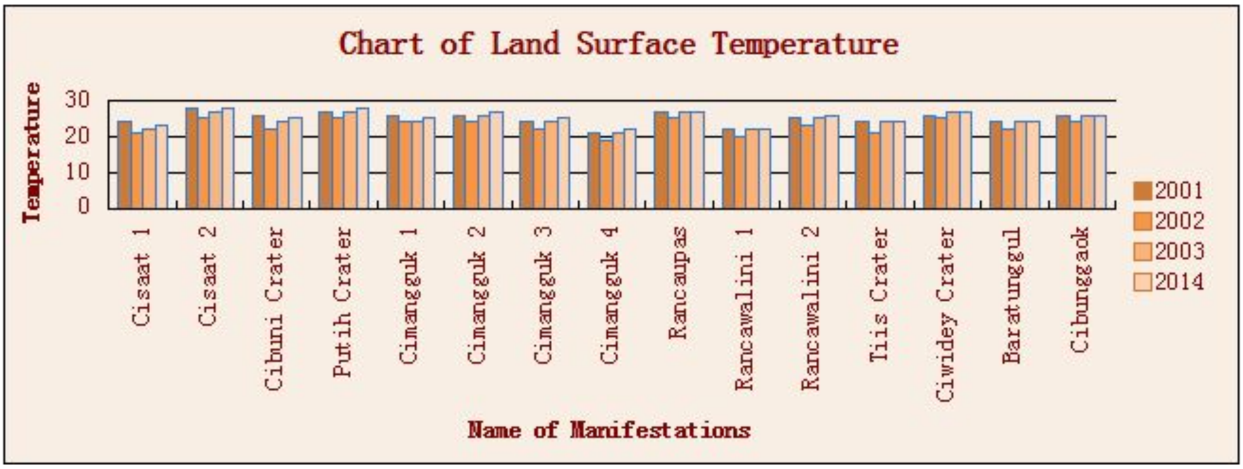

Figure 7 Chart of land surface temperature

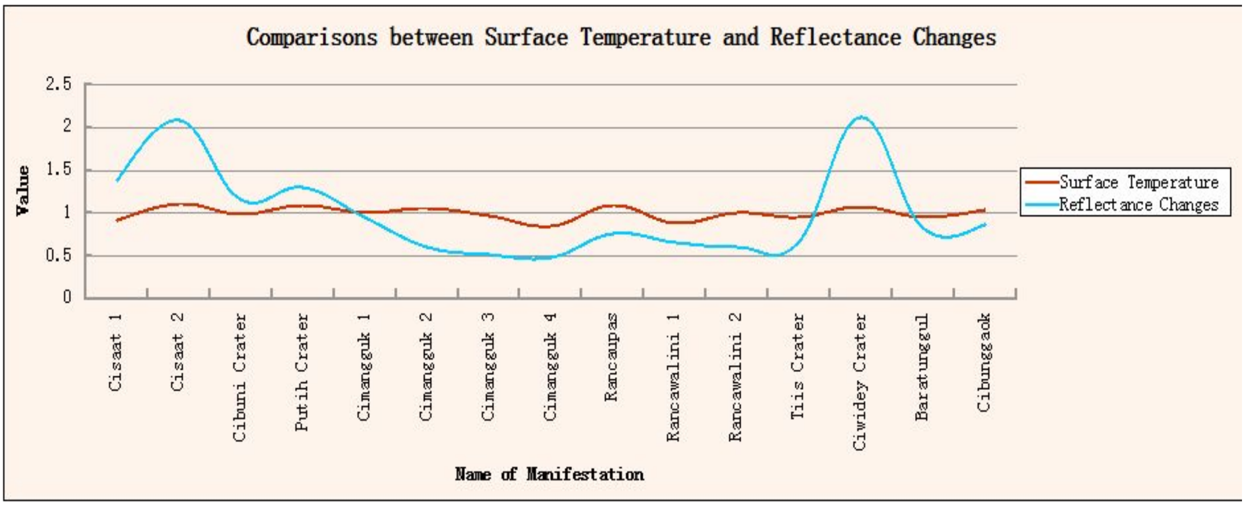

Figure 8 Comparisons between temperature and reflectance

From **Figure 6**, it showed there were 2 surface manifestations (Ciwidey Crater and Cisaat 2) that become anomaly because of their high reflectance changes value. These surface manifestations also have highest land surface temperature (+- 27°C), it showed on **Figure 7**. In addition we looked at the surface manifestation with the lowest changes (Cimangguk 4), it also has the lowest surface temperature (+- 20°C). From **Figure 8**, it concluded that surface temperature was related with some reflectance changes. But temperature is not only the factor, because at another surface manifestation that has high temperature (Rancaupas and Putih Crater) but the reflectance changes are average.

5. CONCLUSION

The optical sensor data with fully-atmospheric and geometric corrected were proved effective to improve the quality of surface detection. Good geometric correction with RMSE below 0.5 caused all the images aligned to the same position. So that the surface manifestations positions could be recognized precisely. As well the atmospheric correction process, the effects of atmosphere have been reduced so that the DN in each image is in conformity with the reflectance values of the targets. In addition, atmospheric correction for the thermal band produced temperature value that free from atmospheric and environment effects. The surface temperature data were useful to validate the position of the surface manifestation. In this study we could detect ground surface changes at geothermal surface manifestation. The changes at ground surface manifestations are detected based on reflectance changes in Landsat imageries. The reflectance changes were validated using stable reflectance of vegetation and bare land. Based on temporal reflectance analyses, surface manifestations at Rancawalini to Baratunggul have same reflectance spectra pattern and surface temperature. On the other hand, the reflectance spectra and surface temperature at Cisaat 2 is similar to the Ciwidey Crater. The reflectance changes at surface manifestation were interpreted due to hydrothermal activities that affect clay minerals at surface. The change of hydrothermal circulation or composition caused changes of soil composition and/or minerals.

6. REFFERENCE

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