The analysis of Surface Temperature Anomalies at Arjuno-Welirang Geothermal Prospects Using Multitemporal Thermal Infrared (TIR) Remote Sensing Data

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Abstract - Remote sensing data have been used widely in geothermal exploration. In this study, Landsat-8 TIR data are used to analyze temperature anomalies at Arjuno-Welirang geothermal field from 2013-2016. Radiometric calibration, atmospheric correction, and emissivity calculation as single channel algorithm parameters are utilized to calculate the Land Surface Temperature (LST). The results show that in the LST Anomalies in 2013-2016 have values between -50,32°C and 35,18°C. Five-point in-situ data of study area and secondary data have a good correlation with the analysis of LST, so that the combination of these data are suitable to be used in the analysis of the surface temperature of geothermal prospect areas.

Keywords – TIR Remote Sensing, Arjuno-Welirang, Land Surface Temperature (LST)

INTRODUCTION

Geothermal energy is the natural heat energy from within the Earth that is transferred to the Earth's surface by conduction and convection [1]. Remote sensing data for geothermal exploration purposes can be used to determine the appearance of the objects of geological surface, like geological structures (faults, joint, lineament), identification of rocks, manifestation of geothermal such as: hot springs, fumaroles, mud pools, and temperature anomaly detection [2]. In this study, remote sensing techniques of Thermal Infrared Remote Sensing (TIR) of Landsat-8 from 2013 to 2016 is applied to the analysis of surface temperature anomalies at Arjuno-Welirang geothermal prospect area combined with secondary data from Geological Resources Center (PSDG) and five-point *in-situ* data in order to support preliminary exploration.

METHOD

The stages of data processing of TIR Landsat-8 to estimate of Land Surface Temperature (LST) includes radiometric calibration to convert the Digital Number (DN) into the radiance [3], atmosphere correction using 6SV model, and calculation of Land Surface Emissivity (LSE) using proportion of vegetation or vegetation fraction cover derived from Normal Differential Vegetation Index (NDVI) [4]:

$$NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}} \quad (1)$$

where R_{nir} is near infrared reflectance (band 5) and R_{red} is red reflectance (band 4).

Proportion of vegetation, P_v:

$$P_v = \left(\frac{NDVI - NDVI_S}{NDVI_V - NDVI_S}\right)^2 \quad (2)$$

where $NDVI_v$ and $NDVI_s$ represent the NDVI of vegetation and soil, respectively [5].

Then, LSE (ε) is calculated by using the following equation [6]:

$$\varepsilon = 0,004 P_v + 0,986 \quad (3)$$

Single-channel algorithm is applied to estimate of LST [7]:

$$LST = \frac{BT}{1 + \lambda\left(\frac{BT}{\rho}\right)\ln\varepsilon} \quad (4)$$

BT is Brightness Temperature in °C of Landsat-8 TIR band (band 10 and 11) [3]; $\rho = hc/j$ in mK unit, where h is Plank constant ($6,626 \times 10^{-34}$ Js), c is velocity of light ($2,998 \times 10^{8}$ ms^{-1}), j is Boltzmann constant ($1,38 \times 10^{-23}$ JK^{-1}), and λ is the wavelength of emitted radiance (12,01 μm).

RESULT AND DISCUSSION

TABLE 1. LANDSAT-8 DATA PROCESSING RESULT

Date Acquired	NDVI		LSE		LST (°C)	
	Min	Max	Min	Max	Min	Max
Jun 26, 2013	-0,52	0,86	0,99	1,00	15,91	25,9
Sept 1, 2014	-0,34	0,76	0,99	1,00	10,38	26,28
Oct 22, 2015	-0,24	0,67	0,99	0,99	20,80	35,18
May 1, 2016	-0,11	0,42	0,98	0,98	-50,32	18,98

Based on the Landsat-8 processing, it is showed that the highest temperature anomaly is in 2015 (20.80°C to 35.18°C) and the lowest is in 2016 (-50.32°C-18.98°C). However, the data of 2016 has a very thick cloud cover and it covers an area of study that affects the data processing.

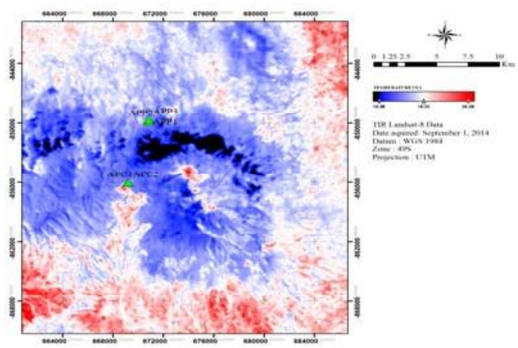

FIGURE 1. LST MAP (SEPTEMBER 1, 2014)

Five-point temperature measurement of study area are taken on Padusan hot spring (APP1, APP2, and APP3) and Cangar hot spring (APC1 and APC2). These *in-situ* data show that the highest temperature is 26.5°C in APP2 and the lowest is in APP3 with 22.5°C. Temperatures in the APP are greater than in the APC. It is consistent with the conclusions of integrated survey (geology, geochemistry, and geophysics) in 2010 by the PSDG that the potential Arjuno-Welirang geothermal prospect is located in the hot spring of Padusan and Cangar, where the reservoir of geothermal is at a depth of about 1500 meters and deeper towards the north and south-west (about APP).

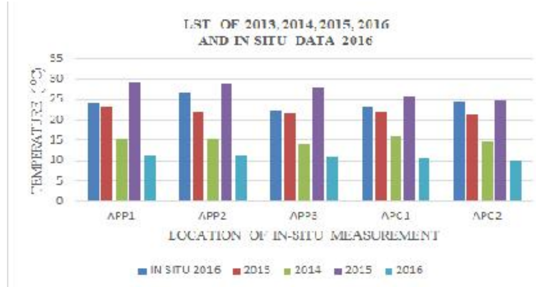

FIGURE 2. LST IMAGERY PROCESSING DATA AND IN-SITU DATA

CONCLUSION

Based on data analysis of Landsat-8 with the implementation of the algorithm of single channel, the surface temperature anomalies in area of Arjuno-Welirang geothermal prospect in 2013-2015 are in interval of 10.38°C to 35.18°C. However, the data in 2016 did not provide accurate information. The results of PSDG integrated survey conclude that potential of Arjuno-Welirang geothermal prospect is located in the hot spring of Padusan and Cangar which is also showed by the LST analysis of Landsat-8 data. Estimation LST surface temperature geothermal prospect area using TIR remote sensing data is an efficient technique but it needs to be supported by geo-science data (geology, geophysical, and geochemical) and climate data.

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