The Sector Development at Tanjung Sakti, Mount Dempo, Bengkulu by Using Integration of Remote Sensing Data and TOPEX Gravity Satellite

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Abstract Mount Dempo is the highest volcano in South Sumatra, which lies between the Bukit Barisan mountains and Gumai. The mountain located in Dempo Makmur Village, Sub-district of Pagar Alam, Lahat Regency, South Sumatra is located at an altitude of 3173 meters above sea level with coordinates of 4.03 ° S 103.13 °E. Mount Dempo’s morphology is formed by pyroclastic deposits consisting of Tuff and Sand rocks. Mount Dempo’s vegetation is dominated by Cassia sp. and Camellia sinensis for upper vegetation, while Strobilanthes hamiltoniana and Strophanthus membranifolium dominate the undergrowth. The purpose of this study is to identify geological structures to predict geothermal prospect areas by integrating remote sensing data and TOPEX Gravity Satellite Data. The remote sensing data used in this study is Landsat 8. This data is used to analyze Land Surface Temperature (LST) from a single thermal infrared band, surface emissivity based on Normalization Difference Vegetation Index (NDVI) from the study area and determine structure delineation. Gravity Satellite Data is used to map gravity anomalies in the volcanic complex of Mount Dempo. Gravity data processing produces a high anomaly zone in the northern part of the study area and is predicted as a prospect area because it is assumed to be related to the plutonic body. High density contrast indicates that there is an error in that area. In line with the error, there are several hot springs because the error serves as a pathway for geothermal fluid to rise to the surface. The study believes that with all the facts stated above, the spots which are located in Tanjung Sakti, Mount Dempo district are very prospective to be developed as a geotourism complex, in which could also increase the welfare of the local citizens.

Keywords: Landsat 8, Topex, Mount Dempo, Sector Development

1. Introduction

Indonesia has many mountains, one of them is located in South Sumatra with an altitude of 3173 meters above sea level called Gunung Dempo as can be seen on Figure 1 with coordinates of 4.03 ° S 103.13 °E. Mount Dempo is the highest mountain in South Sumatra which has seven craters at its peak. The rocks at Mount Dempo consist of Tuff and Sand rocks which are tertiary deposits. Tertiary deposits are derived from andesite lava – basaltic and pyroclastic flows that are deposited. The geological structure that can be found on Mount Dempo are shear fault (dextral and cynical), normal fault, joint around its peak, and topographical damage (VSI ESDM, 2014). Mount Dempo has a type of volcano strato. The last eruption of the mountain occurred in 2009. When the mountain, which is located in Dempo Makmum Village, Pagar Alam, South Sumatra erupted, it emitted ash rain with a distance ± 10 Km. The character of the eruption from the volcano was a freatik eruption. The status of Mount Dempo is at level 1 (normal). Around Mount Dempo also has geotourism potential. There are four natural tourism, namely Pucak Gunung Dempo Crater, Dempo Tea Plantation Area, Singga Kudai Waterfall, Lawang Agung Waterfall and megalithic sites history srriwijaya.
2. Data and Methodology

- **Landsat 8**
  
  This study uses Landsat 8 imagery data with the path in the southern hemisphere 48 UTM coordinate system, which can be obtained from the download of USGS EarthExplorer. Use ArcGIS 10.8 software to process Landsat 8 images to obtain vegetation index and land surface temperature maps.

  1. **Vegetation Map**

     NDVI is a method of measuring vegetation velocity by comparing the spectrum between NIR waves and Red waves. In Landsat 8's OLI sensor, NIR is level 5, while Red is level 4 (Ardiansyah, 2015). NDVI is calculated by the formula below:

     \[
     \text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}
     \]  

     (1)

  2. **Land Surface Temperature**

     To identify land surface temperature, band used in Landsat 8 as the thermal wave is band 10 and band 11

- **Gravity Satellite (TOPEX)**

  TOPEX or Poseidon is a satellite launch by NASA and CNES on 10th August 1992 to map the topography of ocean. The satellite was operated from 1992 until 2005. This is a geodetic satellite whose purpose is to provide high-precision global sea level (ocean height) measurements in coordinates relative to the center of the earth (Space News, 1992).

  The satellite's orbit is a circular, non-sun-synchronous, nearly circular frozen orbit with an altitude of 1,336 kilometers, a period of 112.4 minutes, an inclination of 66.039°, and a repetition period of about 10 days (127 revolutions, equivalent to 9.9156 days) (P. Gaspar, 1994).

  The total gravity data acquired from the satellite for this study is 64 points which mostly covered the Dempo Caldera area. Moreover, it is arranged in gridding with spacing for each point about 1km in TOPEX measurement as can be seen on Figure 2.
3. Results and Discussion

- Landsat 8 Data
  1. NDVI

  According to the results of data processing, the minimum NDVI value is -0.307692, and the maximum NDVI value is 0.664967. On the vegetation map (Figure 3), the green area has a higher NDVI value, while the blue area has a lower NDVI value.
The NDVI value is low because the surface of clouds and water reflects more visible wave energy than near-infrared light, while a high NDVI value (green area) indicates higher vegetation because the surface of vegetation reflects more radiation than infrared wavelengths many visible light.

This NDVI cannot be used as a reference for distinguishing vegetation objects from non-vegetation objects. There is no clear and consistent threshold for the NDVI value, because the NDVI value always changes with the seasons (Ardiansyah, 2015).

2. Land Surface Temperature

![Figure 4. LST Map of Tanjung Sakti, Mount Dempo](image)

The maximum surface temperature is in the range of 34°C, which is indicated in red, while the minimum temperature is 15°C, which is indicated in blue (Figure 4). The highest surface temperature in the northeast of the region. The area is suspected to be the Tanjung Sakti exploration area in Tempo.

- Gravity Data
  1. Complete Bouguer Anomaly

The complete bouguer anomaly map can be seen on Figure 4. The value ranges from 121.8 to 184.8 mGal and the average density derived from pararnis method is 1.1359 g/cm3. As can be seen on Figure 5, high anomaly gravity zone spotted at southwest direction extend to northeast direction.

Based on the geological map, the high anomaly zone covered almost the ancient caldera which assumed it might be related with high density value of volcanic rock. While on the east and northeast direction low anomaly zones are spotted which represented by green and blue color. The low anomaly zone on the northeast direction interpreted might be associated with the presents of the remain caldera wall.

Further study is needed to predict the geothermal prospect area due to the variative interpretation which can be conclude from the gravity anomaly only. Thus, additional data is needed to get better interpretation.
Figure 5. CBA Map of Tanjung Sakti, Mount Dempo

2. Regional Anomaly

Regional anomaly and residual anomaly was separate by using spectrum analysis using Oasis Montaj software. The result of regional anomaly can be seen on Figure 6. The anomaly is lookalike complete bouguer anomaly shown in Figure 5. The tendency of high anomaly zone extends from southwest to south east direction. Considering the study location which located in the volcanic complex, probably the high anomaly zone related with volcanoes which might be intrusive body.

Moreover, consider that regional anomaly images deeper anomaly at the study area, can be interpret that this high anomaly zone extends as it goes deeper. Thus, to get better image of high anomaly zone extension 2-D modelling and upward continuation should be done.
Figure 6. Regional Anomaly Map of Tanjung Sakti, Mount Dempo

3. Residual Anomaly

By separating the regional and residual anomaly, residual anomaly was conducted as can be seen on Figure 7. The pattern of residual anomaly does not look alike either the CBA or Regional map. As can be seen on the picture, the residual anomaly tends to show shallower anomaly which is more variative and tend to be affected by noise. Thus, several small closures show there.
Figure 7. Residual Anomaly Map of Tanjung Sakti, Mount Dempo

- **Sector Development Area**

  Pagaralam City, one of the cities in South Sumatra located on the slopes of Mount Dempo holds historical relics. Megalithic relics are scattered at several points of the city. The relics are menhir, dolmen, stone coffins, dimples, and statues of stones in a static and dynamic style (Kherti, 1953).

  In Basemah, menhirs were found stand alone or in group and form formations, and often side by side with other buildings. On the deep reef, a plain menhir found 1.6 meters high, standing on a rock. In the hamlet of Tegurwangi, there are also many plain menhirs 1.5 meters high near dolmens, statues and stone coffins. In addition to menhir, dolmens are also found in the city. The best dolmen is located in Batucawang. Dolmen stone board measuring 3 x 3 m with a thickness of 7 cm, located on top of 4 supporting stones. Another megalithic that has been found is a stone statue depicting the shape of an animal.

  The most interesting discovery is a megalithic called "Batugajah". Batugajah is a piece of egg-shaped stone, measuring 2.17 m long and carved all over its surface as can be seen on Figure 8.
4. Conclusions
Based on remote sensing data analysis, the sector development zone is located in the center of this study area, because it has high surface temperature in NDVI. This area also has high gravity anomaly in Gravity Satellite. The high anomaly value in the center area might be associated with ancient intrusive body owned by Dempo caldera or possible heat source of geothermal system. Further study in this boundary should be done to give advance identification of geothermal prospect zone at Dempo geothermal prospect area. And also the site history study believes that with all the facts stated above, the spots which are located in Tanjung Sakti, Mount Dempo district are very prospective to be developed as a geotourism or tourism, in which could also increase the welfare of the local citizens. By integrating the local culture diversities and geodiversities, we believe that this paper could give a new insight for the local people to develop their geotourism potential where their priceless natural diversities are located.

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References
[1] Ardiansyah. 2015. Remote Sensing Image Processing Using ENVI 5.1 and ENVI LiDAR. PT Labsig Inderaja Islam, Jakarta.
[2] Official website vsi ESDM. 2014. G. Dempo. Retrieved October 8, 2020, via vsi.esdm.go.id
[3] Official website of Magma Indonesia. 2020. Dempo Volcano Activity Report. Retrieved October 8, 2020, via magma.esdm.go.id
[4] P. Gaspar, F. Ogor, P. Y. Le Traon, O. Z. Zanife. 1994. Joint estimation of the TOPEX and Poseidon sea-state biases. Journal of Geophysical Research. Vol. 99 (Preprint 24981-24994)
[5] Topex-Poseidon Partners Discuss Sequel', Space News, Aug. 17-23, 1992, p. 3
[6] Kherti. 1953. Official website of Pagar Alam City Government. 2018. Megalit Basemah. Retrieved 10 October 2020, via pagaralamkota.go.id