Remote sensing and GIS for land conservation: identification of post-tin mining land conservation in Perimping Sub Watershed

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Abstract. Perimping sub-watershed is part of a mayor watershed in Bangka Regency where the expansion of tin mining was very high since 2001. However, this watershed still categorized as Priority II which mean it has to be maintained and retained for any changes. Environmental management program such as land conservation of post-tin mining area was contributed to maintained the condition around watershed which damaged by mining activity. This study aimed to identify the distribution of post-tin land conservation in Perimping sub-watershed based on land surface temperature and NDVI data in term of 2001, 2009, and 2017. Landsat 5 TM and Landsat 8 OLI/TIRS were used to estimate LST and NDVI. Google Earth imagery also used to identify the landcover change of land conservation. The result showed the average of LST around post-tin mining area were decreasing from high in 2001 (31°C-35°C) to moderate in 2017 (26°C-30°C). Yet the NDVI showed enhancement trend from low (0.1-0.25) to high (0.51-0.70). Both LST and NDVI distributed in the centre of Sub Perimping Watershed Area which indicate that the density of vegetation cover around post-tin area is increasing as the result of post-tin land reclamation and revegetation program.

1. Introduction

Perimping sub-watershed is part of a mayor watershed in Bangka Regency where the expansion of tin mining was very high since 2001. Especially were occupied by unconventional miners (TI) since the issuance of Bangka Regency Local Regulation No.6/2001 concerning of Mining Business License [1]. However, this region is still classified as Priority II watershed. Watershed which classified in Priority II is a watershed that must be maintained its natural condition.

The expansion of tin mining area can turn the vegetated area into a bare land [2]. Tin mining activity also caused a lack of soil fertility, degradation of water quality, damage to ecosystems that cause loss of certain vegetation variation and caused changes in microclimate conditions [3]. The environmental damage especially the land degradation land due to mining activity can be minimized by conserving the land.

Land conservation aimed to restore and protect degraded land, so that the land can be more productive [4]. Conservation of post mining land provided by land reclamation and revegetation [4].

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Conservation activities of post-tin mining area in the Perimping Sub-watershed have been conducted by PT. Timah, Tbk, but its activities were discontinued in 2001 as conservation land was reoccupied. Those caused post-tin mining conservation activities to be inadequate and difficult to be identified. However, the conservation was re-enacted in 2006 [5].

The study of the biogeophysical condition of the mining area showed that post-mining land revegetation activities can affect the land surface temperature (LST) condition. Post-mining land that has been conserved primarily by the revegetation process indicates a decrease in surface temperatures around the mining area [6]. Therefore, the identification of post tin mining land conservation location can be done by utilizing information about changes in vegetation density (NDVI) and changes in surface temperatures around the tin mining area. NDVI represents the level of vegetation density and also as one of climate element control parameters [7,8]. While, the LST indicated the absorption rate of an earth surface against solar radiation [8] which is also related to the vegetation density (NDVI) [9,10]. NDVI and LST were obtained by processing Landsats 5 TM imagery in 2001 and 2009 also Landsat 8 OLI / TIRS in 2017.

Mine areas are kind of vulnerable ecosystem [6] and so does the watershed area. This study aimed to determine the distribution of post tin mining conservation location. The information of conservation location might very important to evaluate the conservation activities that have been done. Management and conservation of the watershed area is an important step to maintain sustainability of its natural resources and the natural watershed ecosystem [11].

2. Materials and Methods

2.1 Study Area
This research was conducted in Bangka Regency. Precisely include tin mining and its surrounding area in Perimping Sub-Watershed. The Perimping Sub-Watershed is actually part of one of a large watershed, named DAS Layang. The width of the Perimping Sub watershed area is 265.12 km². Topographic conditions of the region in the dominance of flat slopes with low altitude.

2.2 Data dan Processing
The data used in this research is the data of the mine area (shape file data) obtained by digitization from Google Earth imagery in 2001, 2009, and 2017 then adjusted to data WIUP PT. Timah, Tbk. Moreover, Landsats 5 TM image data in 2001 and 2009 and Landsat 8 OLI / TIRS 2017 were used to obtain NDVI and LST values. Post tin mining conservation can be determined if there was an increase in NDVI value and a decrease in LST value in tin mining and surrounding areas between 2001, 2009, and 2017. This indicates a conservation process in the form of revegetation activity [7].

The value of NDVI in this study was obtained by calculating NIR band (infrared band) and RED (red band) on each image. Band NIR in Landsat 5 TM is band 4 (0.76µm-0.90µm) and Band RED is band 3 (0.63µm-0.69µm), while in Landsat 8 OLI / TIRS band NIR is band 5 (0.84µm-0.88µm) and band RED is band 4 (0.63µm-0.68µm). The following is the equation used in obtaining the NDVI value [9].

$$NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$ (1)

LST represents the temperature value of an object on the surface of the earth. The value is obtained by converting the digital number into a spectral radiance value in celcius units. The following are the equations used to obtain the LST value [12].

$$L\lambda = \frac{L_{MAX} - L_{MIN}}{Q_{CAL\ MAX} - Q_{CAL\ MIN}} (Q_{CAL} - Q_{CAL\ MIN}) + L_{MIN}$$ (2)
Where $L$ is spectral radiance (Wm$^{-2}$sr$^{-1}$µm$^{-1}$), $L_{Max}$ is the maximum spectral radiance, $L_{Min}$ is the minimum spectral radiance, $Q_{Cal ~Max}$ is the maximum pixel value in digital number and $Q_{Cal ~Min}$ is the minimum pixel or digital number. Then the spectral radiance value is converted to Kelvin as (LST) estimation with the following equation.

$$T_{-rad} = \frac{K2}{\ln \left( \frac{K1}{L_{\lambda}} \right) +1} \quad (3)$$

$T_{-rad}$ is the temperature radian (Kelvin), $K1$ and $K2$ are calibration constants, and $L_{\lambda}$ is spectral radiance (Wm$^{-2}$sr$^{-1}$µm$^{-1}$). Then the LST value in kelvin minus 273.15 to obtain the LST value in degrees celcius.

Both the NDVI and LST values is then classified into 5 classifications. The classification consists of very high to very low. The classification performed to show the diversity of NDVI and LST in the Perimping sub-watershed area. Each classification can be observed in Table 1 and Table 2. Once the value of NDVI, LST, and estimated tin mining conservation location has known, field validation was conducted to observe the condition of land conservation in the field.

| Classification | NDVI       | Classification | Temperature (ºC) |
|----------------|------------|----------------|-----------------|
| Very Low       | <=0        | Very Low       | <20             |
| Low            | 0.1-0.25   | Low            | 20-25           |
| Moderate       | 0.26-0.50  | Moderate       | 26-30           |
| High           | 0.51-0.70  | High           | 31-35           |
| Very High      | >0.70      | Very High      | >35             |

2.3 Statistical Analysis

To reinforce the fact that the reclamation and revegetation process conducted on post tin mining area can affect the surface temperature in the area, a correlation test or R test is conducted to determine whether there is a relationship between NDVI and LST changes or not [9]. Besides, the overall accuracy test of the conservation site sample point was to determine the accuracy data that has been processed compared by real field condition. The equations for overall accuracy are as follows, where $N$ is total number of sample [13].

$$Overall ~ Accuracy = \sum_{i=0}^{n} \frac{ni}{N} \quad (4)$$

3. Results and Discussion

3.1 Spatial Distribution of NDVI and Land Surface Temperature (LST) in Perimping Sub-Watershed

Based on the results of NDVI and LST processing, there was a tendency that showed increasing of vegetation index (NDVI) and decrease of LST in the surrounding tin mining area. The statistical correlation test of 35 samples based on NDVI and LST data indicates that the change in LST has a relationship influenced by NDVI in the same location at the mining area in the Perimping Sub-watershed.

| NDVI | Land Surface Temperature | NDVI | Land Surface Temperature |
|------|--------------------------|------|--------------------------|
|      | 2001                     |      | 2009                     | 2017                     |
| R    | -0.75                    |      | -0.88                    | -0.79                    |

The value of the relationship between NDVI and LST (Table 3) shows the negative value or shows the inverse relation. Mostly negative correlation between NDVI and LST happened when the area in
warm season and dominated by dry land [9]. NDVI and LST anomalies between 2001, 2009, and 2017 based on 35 samples are presented in the graph (Figure 1). The graph illustrated that the low NDVI conditions also followed by high surface temperatures and vice versa.

3.2 Identification of Post-Tin Mining Conservation in Perimping Sub-Watershed

NDVI and LST values in the mining areas of the Perimping Sub-watershed show fluctuations between 2001, 2009, and 2017 (Figure 2). NDVI in the mining area shows very low density (<= 0), while the surrounding area is low (0.1-0.25), evidenced that the tin mining activity contributed to decreased levels of vegetation density in an area with irregular landscape due to the accumulation of tailings [2]. While the LST of mining area in Perimping Sub-Watershed in 2001 was dominated by very high (> 35 °C) surface temperature which concentrated in the occupied aerial, while was categorizes as high (31 °C-35 °C) in the surrounding area.
In 2009 the value of NDVI in the northern mining area showed moderate category (0.26-0.50) and a small percentage categorized (0.51-0.70). Condition of surface temperature of the mainland in the mining consider any change, although not significant. In northern mining area there is a surface temperature in the medium category between 26°C-30°C which is isolated between high and very high temperatures. Indicates an increase in vegetation density as result of land conservation causing a decrease in surface temperatures. Based on the data obtained in the field, mining in the northern sub-watershed has been done reclamation and land revegetation by PT Timah, Tbk between 2006-2007, which in past two years has shown the development of vegetation density.

In 2017 tin mining activities were more active compared to 2001 and 2009. The LST change which was categorized high in 2001 and 2009, changed into low categorized (20°C-25°C) in 2017. Similarly, vegetation density conditions showed a moderate to very high increase (> 0.70). Then to complete the results of the analysis conducted field validation to compare the distribution of conservation location of the results of data processing with the actual location. Sampling distribution maps and post tin mining conservation sites can be observed in Figure 4. The accuracy of sample and existing comparison showed 76%. The overall accuracy close to 80% are still considered feasible to represent the results of data processing. Although the most appropriate degree of accuracy based on image interpretation is >= 80% [10]. Sampling distribution maps and post tin mining conservation sites can be observed in Figure 3.

![Figure 3. Map of Conservation Location Sample](image)

Validation of post tin mining site conservation location in the field shows that conservation was done by different actors. The characteristics of post-tin mining land conservation showed variations in the form of vegetated overburden, vegetated and non-vegetated tailings, slime not vegetated, and ‘kolong’ with varying depth. In the location No.1 of post-mining land conservation was conducted by PT Timah Tbk in the period of 2007-2010. The average LST at that location was 28°C or categorized as moderate (26°C-30°C). The condition of the conserved land is currently dominated by shrubs and stands such as sengon (Albizia chinensis).

Location No.2 of post-mining land conservation was done by one of the plantation parties. Plant commodities grown on post tin mining sites are oil palm. The environment for land conservation is intimately tied to economic activity in a region [14]. The location of plantations in the field was known adjacent or neighboring the mine site, and the location of oil palm plantations using post mining land as a growing medium. Location No.3 of conservation in the form of land revegetation conducted by Indonesian Institute of Science (LIPI) and The House of Representatives of The Republic of Indonesia (DPR RI) in 2017. Plants used are Plasma Coconuts and some types of
overcrop. The surface temperature at this location is still relatively high due to the existing vegetation has not completely covered the mining area.

4. Conclusion
Remote sensing data such as Landsat 5 TM and Landsat 8 OLI / TIRS imagery processed by utilizing GIS devices can be use in identifying the location of post-mining tin conservation. The vegetation density (NDVI) levels were getting higher in the periods of 2001, 2009, and 2017. The change was also followed by a decrease in surface temperatures in 1°C. These conditions indicate the existence of post-tin mining conservation activities. Post-tin mining conservation was not just contributed by mining entrepreneurs but also the government in cooperation with Education Institution and also by plantation sector. The goal is the same so that post-mining tin can be made more productive land for the community and regional economy.

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