Analysis Of Land Exploitation And Reclamation In Coal Mining Land Based On Vegetation Index Using Sentinel-2 Data (Case Study In The City Of Sawahlunto, West Sumatra Province)

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Abstract. This study aims to identify the distribution of land that is subjected to exploitation and land that is reclaimed after coal mining in Sawahlunto city based on the vegetation index. The Vegetation Index was obtained from the results of the NDVI image transformation analysis, then the dNDVI method was used which was obtained from the reduction of NDVI results in the year before the land change and NDVI in the year after the land change in the coal mine area on the Sentinel-2 image. The results of the dNDVI analysis obtained the threshold value of the vegetation index which was used to identify land that was subjected to exploitation with a value of >0.345, land that was not affected had a threshold value between -0.1345 to 0.345, then land that underwent reclamation had a threshold value of < -0.1345. Based on this study, it can be concluded that the vegetation index can identify land changes in the mining area by applying several threshold values to divide the classification of land changes contained in the mining area.

Keywords: dNDVI, Exploitation, Reclamation, Sentinel-2

1 Introduction

Fossil energy is still the main source of energy in supporting people's lives today. One of the minerals used as fossil fuels for energy acquisition is coal. The acquisition of coal minerals is usually done by mining, be it by surface mining or underground mining. Coal mining that is often carried out is surface mining because it generally provides an efficient approach to achieving high production (Shrestha & Lal, 2011). In the process of mining coal minerals, the process of exploitation on surface mining often has an impact on land changes at coal mining sites. Surface mining results in : (i) removing vegetation, (ii) changing landscapes and landscapes, (iii) changing soils, and (iv) drastically disrupting hydrological systems (Ahirwal & Maiti, 2016; Kumar et al., 2015). The land change causes the loss of vegetation due to land clearing for coal mining, so it is feared that the land will lose its ability from what it should be and eventually become critical land if the reclamation process is not carried out.

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The use of remote sensing technology is quite effective in monitoring changes in mining land. The ability of remote sensing vehicles to detect objects on the earth's surface makes this technology a solution for monitoring land within a large area (Jucker et al., 2017). One of the remote sensing vehicles used for land monitoring is the Sentinel-2 Satellite which produces Sentinel-2 Imagery products. Sentinel-2 imagery is a remote sensing satellite image that has a resolution of 10 meters and has 13 spectral channels incorporated in the multispectral sensor system owned by sentinel-2, namely Multispectral Imaging Instruments (MSI) which can detect objects on the earth's surface more specifically (ESA., 2014). By using multispectral sensors owned by satellites that capture the reflection of electromagnetic waves reflected by a variety of different objects on the earth's surface, they can be used for monitoring land cover, climate, and disasters (ESA.,2014; Malenovský et al., 2012).

In monitoring land changes due to coal mines, the use of vegetation indexes obtained from Sentinel-2 imagery can provide concrete spatial information about land changes due to coal mines in an area. The vegetation index is based on red and near-infrared canals on multispectral imagery and then applied to the NDVI method so that when land change analysis is carried out using vegetation indices on two images with different times, the changes will be visible because land changes due to coal mining cause a decrease and even a drastic disappearance of vegetation due to the clearing of mining land for surface mining (Arifin, 2021).

Many land monitoring studies use sentinel-2 imagery as research material, such as land monitoring in agriculture, urban area development, and forest monitoring (Drusch et al., 2012; Pesaresi et al., 2016; Sibanda et al., 2015). However, in this study, researchers limited the research topic to monitoring coal mining land using the NDVI vegetation index from Sentinel-2 Imagery. Then this study aims to identify exploitation land and reclaimed land due to coal mining in 2021 using Sentinel-2 Imagery, then the calculation of exploited land area and reclaimed land due to coal mining is carried out based on the identification results of Sentinel-2 Imagery, and to increase the validity of research results using satellite imagery, a sentinel-2 image classification accuracy test is carried out.

2 Research Methods

2.1 Research Location

The location of this study was carried out on the land of the mining business permit area (WIUP) owned by a mining company that carries out coal mining activities in the administrative area of Sawahlunto City which is located between 0°33'40" – 0°43'33" South Latitude and 100°42'59" – 100°49'60" East Longitude. Administratively, Sawahlunto City consists of 4 sub-districts, 10 sub-districts, and 27 villages. It is bordered by Tanah Datar Regency in the north, Solok Regency to the south and west, and Sijunjung Regency in the east [BPS., 2021].

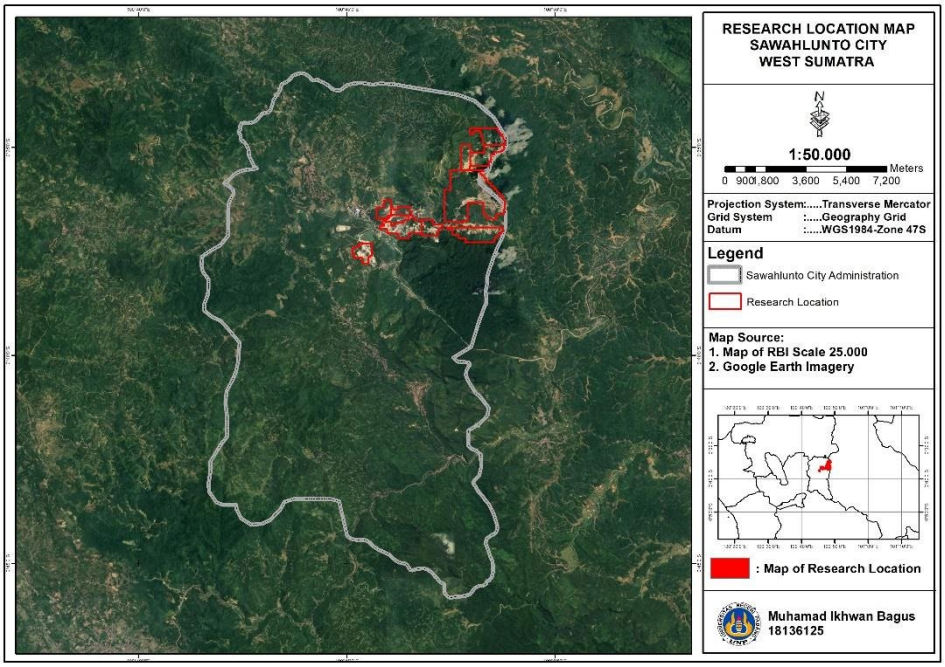


Fig. 1. Research Location Map

2.2 Data

The data used is secondary data sourced from Sentinel-2 level-2A remote sensing imagery obtained in the Google Earth Engine database, in addition to using the Indonesian Earth Aspect obtained on the Inageoportal website from the Geospatial Information Agency (BIG). Then the primary data sourced from the field survey is in the form of land sample points for testing the accuracy of the sentinel-2 image classification results..

Table 1. Data Type and Data Source

Data	Type	Source
Sawahlunto Administration Map	Secondary	Geospatial Information Agency (BIG) Indonesia
Sentinel-2 Level 2A Imagery	Secondary	USGS / Google Earth Engine Database
Vegetation Index	Secondary	Sentinel-2 Analysis
Groundcheck Point	Primary and Secondary	Field Survei and Google Earth Imagery

2.3 Normalized Difference Vegetation Index (NDVI)

This research is the use of remote sensing technology, therefore the method used in data analysis is a method that is widely used in the transformation of satellite imagery, namely Normalized Difference Vegetation Index (NDVI). NDVI is a combination of blasphemy techniques with image reduction techniques, simple indices, and dynamic and sensitive range value results that are very suitable to be applied to see changes in vegetation cover. The algorithm used in this NDVI analysis is as follows:

$$NDVI = \frac{NIR - \mathrm{Re}\,d}{NIR + \mathrm{Re}\,d} \tag{1}$$

The results of the formula have values that range from -1 to 1 with the smaller the value, the lower the level of vegetation in the area. The value of -1 indicates that the red band has a maximum reflection value while the near-infrared band has a minimum reflection as well as the value of +1 indicates the reflection of the near-infrared band is maximum and the red band has a minimum reflection which indicates that the vegetation in the region is high. Comparative calculations of the nature of the object's response to the reflection of red rays and NIR can produce values with distinctive characteristics that can be used to estimate the density or condition of the canopy/greenness of the plant. Healthy green plants have a high vegetation index value. This is due to the inverse relationship between the intensity of the rays reflected by vegetation on the spectral of red rays and NIR. Meanwhile, to determine the change in vegetation from the year before and after being mined the year after, the equation is used:

$$dNDVI = NDVIpre - NDVIpost \tag{2}$$

In the use of the vegetation index to detect land changes due to mining, land affected by exploitation experienced a drastic decrease in the value of NDVI from the previous year, because in the exploitation process there was a massive removal of vegetation and the land turned into the land that did not have vegetation. Then the land that has undergone reclamation, has an increase in the value of NDVI from the previous year because in the reclamation process there is a gradual recovery of vegetation (Xiao et al., 2020).

3 Results And Discussion

3.1 Identification of Coal Mine Exploitation and Reclamation Land in Sawahlunto City

In carrying out the process of identifying the spatial distribution of exploited and reclaimed land, researchers conducted an analysis using Sentinel-2A satellite imagery data from 2017-2021. Then the analysis technique that researchers use in identifying exploitation and reclaimed land is digital image transformation using the Differenced Normalized Difference Vegetation Index

(dNDVI) method which is based on the Normalized Difference Vegetation Index (NDVI) method to obtain the vegetation index of an area. A land change can be identified using the vegetation index (NDVI) when we calculate the reduction in the NDVI before the land changes (NDVI pre) and NDVI after the land has changed (NDVI post).

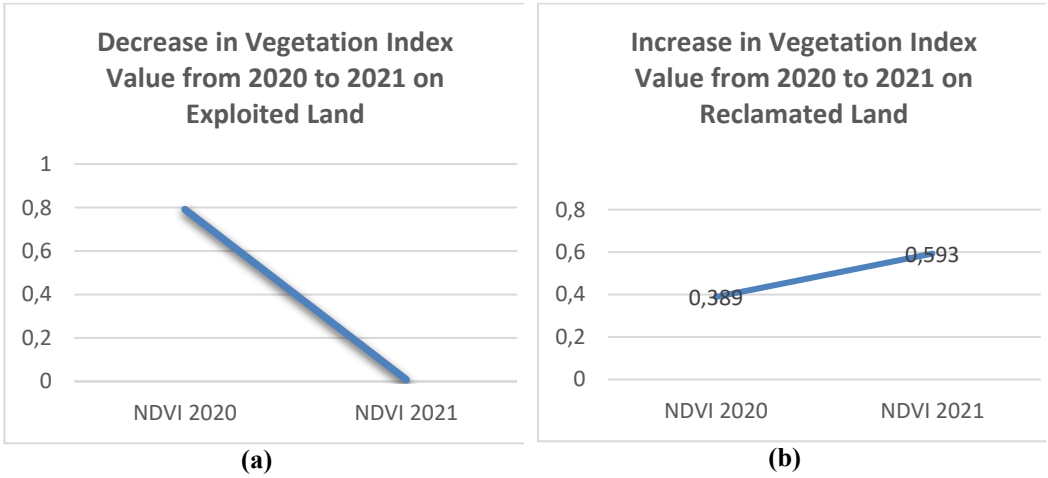
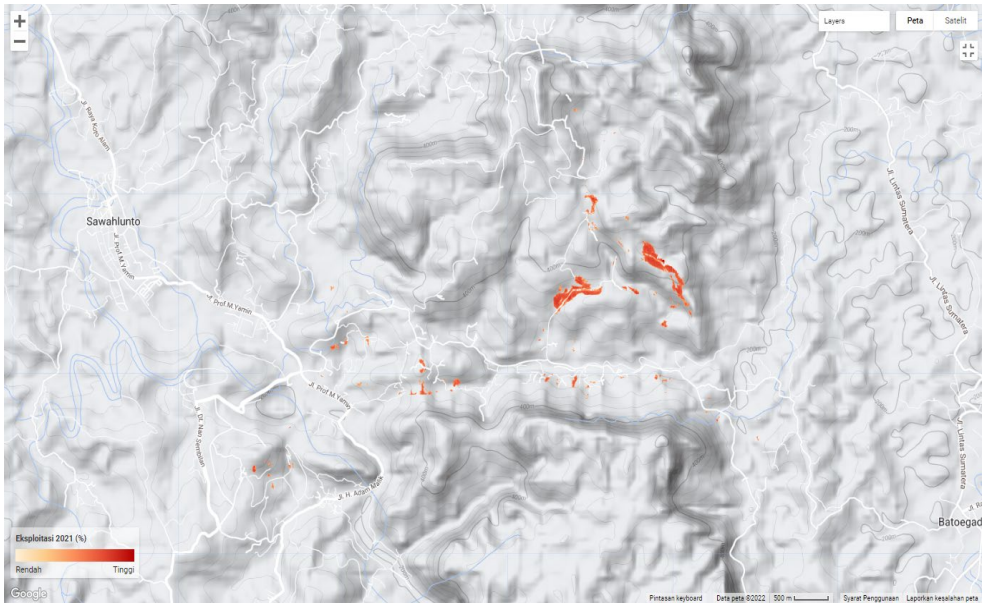


Fig. 2. (a) Graph of Changes in NDVI Index Value from 2020 to 2021 on Exploited Land, and (b) Graph of Changes in NDVI Index Value from 2020 to 2021 on Reclamated Land

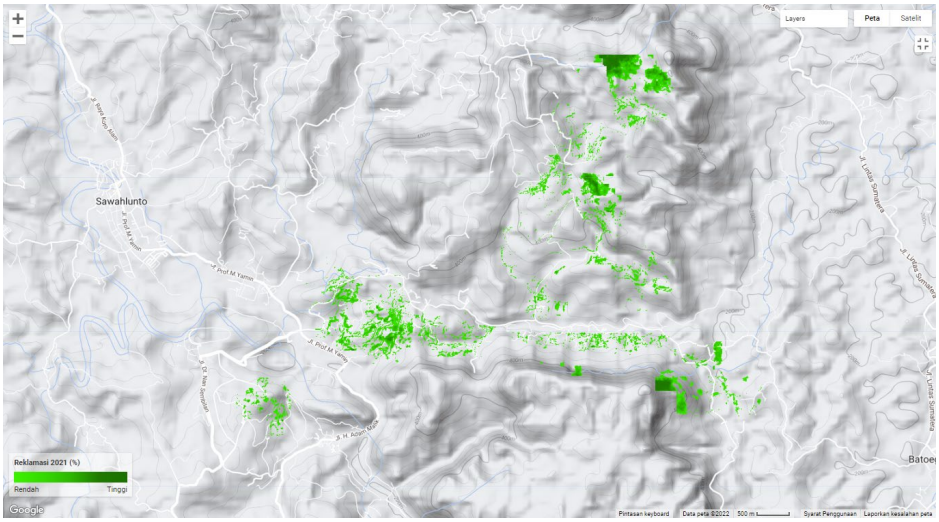
In calculating dNDVI on mining land, it is found that land that is subjected to exploitation has a positive dNDVI threshold value, while land that undergoes reclamation has a negative dNDVI threshold value. Land that is subjected to exploitation has a positive dNDVI threshold value because massive land changes occur within one year, namely changes from land that has vegetation in the previous year (which has a high vegetation index) then land clearing for coal exploitation which results in vegetation loss in the following year (has a low vegetation index). Then the land that undergoes reclamation has a negative dNDVI threshold value because the land affected by reclamation is indicated to have vegetation growth from previously having no vegetation or having a low vegetation level to having vegetation and the vegetation index is increasing. The following is the threshold value of land that has been exploited and reclaimed after analysis using the dNDVI method:

Table 2. Threshold of dNDVI for Coal Mining Land Classification

Classification	dNDVI Threshold
Exploitation Land	≥ 0.345
Unaffected Land	$-0.1345 < dNDVI < 0.345$
Reclamation Land	≤ -0.1345



(a)



(b)

Fig. 3. (a) Exploitation Land n The City of Sawahlunto in 2021, and (b) Reclamation Land in The City of Sawahlunto in 2021

3.2 Land Area Subjected to Exploitation and Reclamation

Table 3. Threshold of dNDVI for Coal Mining Land Classification

Land	Hectare (Ha)
Reclamation Land	162.53
Exploitation Land	28.73

Based on the table above, we can get the trend of land change that has been exploited and reclaimed due to coal mining in Sawahlunto City. This happens because of the massive coal mining activities in Sawahlunto City, especially in the area of coal mining companies that have mining business licenses (IUP). In 2021, the exploited land has an area of 28.73 hectares. Then for land that undergoes reclamation, the land area in 2021 is 162.53 hectares.

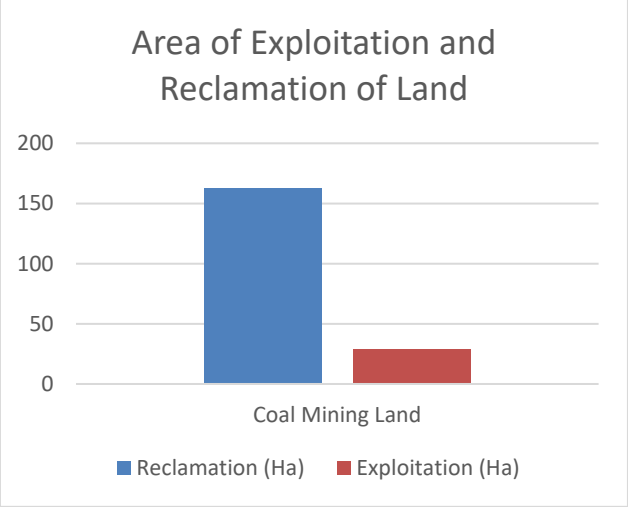


Fig. 4. Graph of Exploitation Land Area and Reclaimed Land in Sawahlunto City in 2021

3.3 Accuracy Assesment

Accuracy tests are needed to determine the level of accuracy of the results of satellite imagery analysis with the actual situation in the field. Accuracy tests are carried out on each classification of mining land, namely land affected by exploitation and land that has undergone reclamation from 2020-2021. The accuracy test was carried out using the Confusion Matrix method, where the degree of accuracy suitability can be said to be high if the overall accuracy value is>85% and the kappa coefficient value >80% (Congalton & Green, 2019).

Table 3. dNDVI Accuracy Assesment on Mining Land in 2021

Imagery Data	Field Data		
	Reclamation Land	**Unaffected Land**	**Exploitation Land**
Reclamation Land	9	0	0
Unaffected Land	1	8	1
Exploitation Land	0	0	9
Total	10	8	10
Producer Accuracy (%)	90	100	90
Overall Accuracy (%)	93.33		
Kappa Coeficient	89.31		

Based on the results of the mining land classification accuracy test using dNDVI in 2021, the results were obtained for the accuracy of classification on reclaimed land by 90%, then the classification accuracy on exploited land by 90%, then the results of the overall accuracy test or Overall Accuracy of 93%. And the result of its Kappa Coefficient has a value of 89.31%. Based on this value, the results of the analysis of the classification of exploited land and coal mine reclaimed land using dNDVI in 2021 have a high level of suitability.

4 Conclusion

The results of the dNDVI analysis using Sentinel-2 level 2A imagery data were obtained spatial information about the land affected by the mine in Sawahlunto City. By using the threshold value, information is obtained in the form of the results of the classification of land affected by exploitation and land that has undergone reclamation. Land affected by exploitation has a positive dNDVI value (>0.345) then land that undergoes reclamation has a negative dNDVI value (< -0.1345), and unaffected land has a dNDVI threshold value (-0.1345 < dNDVI < 0.345). The land affected by the mine (Exploitation and Reclamation) is highly distributed in Talawi District where in the area some companies have IUP to carry out coal mining in Sawahlunto City.

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