Assessing Environmental Impacts of Mining Activities in Kalimantan Using Remote Sensing Approach

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Abstract. Mining activities play an important role in country's economy. On the other hand, this activity poses a serious threat to the environment. This is also exacerbated by the increasing demand for products every year. Kalimantan is one of the largest mining areas in the world, but the existence of this mining area has caused massive deforestation due to land clearing. Monitoring the impact of mining activities on the environment is an important thing in the future. In this study, an assessment of the impact of mining activities on Kalimantan Indonesia was carried out using remote sensing products. The method used in the research is the rate of change with a time span of 2000-2020. Based on the results, there are 315 and 2 mining areas on Kalimantan which are categorized into high and very high environmental quality decline respectively. This research can be used as guide in mitigating environmental impacts.

Keywords: Environment, Mining activities, Rate of change, Remote sensing, Tropical forest.

1 Introduction

Mining, a sector that cannot be separated from human life. Whether consciously or not, various mining products are used by humans every day. In the last few decades, demand for mining products has increased [1], [2] and is predicted to continue in the future [3], [4]. Unfortunately, mining activities have various negative impacts on the surrounding environment [5], [6]. Environmental degradation, disasters, air and water pollution, and the emergence of disease are some of the negative impacts resulting from mining activities [7]–[9]. Areas around mining areas are also vulnerable to changes in land use due to the opening of new mining areas [8], [10]. Increasing demand for mining products can certainly exacerbate the negative impacts received on the surrounding environment. Excessive exploration and exploitation activities can threaten the sustainability of this forest.

Tropical forest areas are a common location for many operating mines to be found. In the period 2000—2019, tropical forest areas have lost an area of 3,264 $km2$ as a direct impact due to mining activities [11]. There are 9,100 (28,902 $km2$) from 44,929 (101,583 $km2$) mining areas in the world located in tropical forest areas and 22.5% of them are in

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Kalimantan, Indonesia [12]. Tropical forests which are generally located close to the equator and are characterized by very high rainfall and basically have high ecological benefits [13]–[15]. Assessment of environmental impacts due to mining activities is important. This is also in line with various international agendas and commitments related to sustainability in environmental and climate change [16]. With a deeper understanding, strategies can be developed to maintain environmental sustainability and create more environmentally friendly mining in the future.

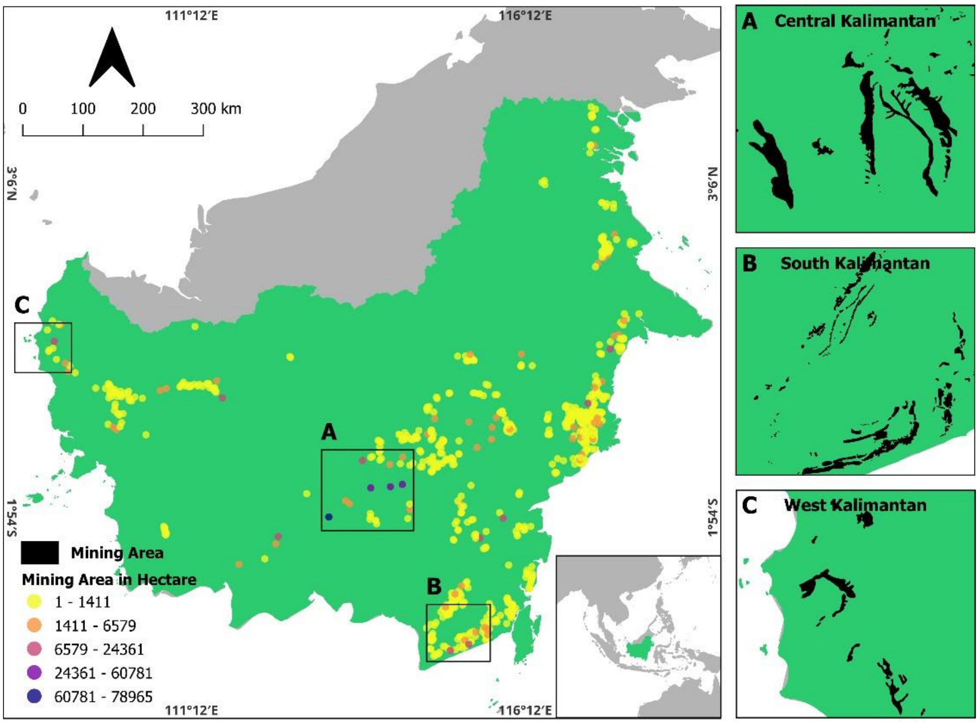
Several previous studies have conducted research to assess the impact of mining activities on the surrounding environment using remote sensing technology. The use of remote sensing technology makes it possible to monitor and assess large areas, access to temporal information, and does not require direct contact to collect data, and quickly [17]–[19]. [20] conducted an environmental assessment in iron ore mining areas in the Qian'an and Qianxi regions of China using remote sensing. [5] conducted research regarding the impact of the Gobi coal mine in China before and after mining activities began using remote sensing. The two studies developed the Remote Sensing Ecological Index (RSEI) with different indicators. [21] used remote sensing data to identify the impact of mining-induced deforestation on land surface temperatures and carbon stocks in the Amazon Forest. There is also research conducted by [11] regarding direct and indirect deforestation due to the mining industry in pantropical areas using a geographic information system approach.

These studies focused on certain mining areas and limited the time span used. There is no research related to assessing the environmental impact of mining activities in Kalimantan's tropical forest areas by reviewing the characteristics of the mining area from surface, atmosphere, vegetation, and soil variables. The research will use the rate of change method over a period of 20 years to understand how trends are formed, so that we can find out which mining areas have a negative impact on the surrounding environment.

2 Material and Methods

2.1 Study Area

Kalimantan is the third largest island in the world which is famous for its biodiversity and abundant natural resources and consists of 2 countries besides Indonesia, namely Malaysia and Brunei Darussalam. Kalimantan is located between $4°24"N - 4°10"S$ and $108°30' E - 119° E$. This research will focus on the Kalimantan region which is in the central part of Indonesia. One important aspect that has become the center of attention is the existence of a mining area which includes several crucial natural resources, making it one of the largest mining areas in the world. However, on the other hand, Kalimantan's environmental sustainability has been threatened due to extensive mining activities. The increasing growth of the mining industry has had a significant impact on Kalimantan's forest ecosystem. **Figure 1** shows Kalimantan Indonesia as the study area.



Mining areas are represented in the form of point taken from the centroid of the area - Data Sources: Maus et al., 2022.

Fig 1. Kalimantan, Indonesia as study area with Central Kalimantan (A); South Kalimantan (B); and West Kalimantan (C).

2.2 Material

In conducting this research, various data were used such as Soil Index (SI) and Normalized Difference Vegetation Index (NDVI) to obtain information on land openness and vegetation density. Backscatter of Synthetic Aperture Radar (SAR) data to obtain surface roughness information. Atmospheric characteristic data is also used to represent the impact of mining activities such as surface temperature and $SO2$ concentration. Table 1 presents the data used along with the sources and data types.

Table 1: Data used and data type.

No	Data	Product	Temporal	Type-Resolution
1	Surface Reflectance Satellite Imagery	MOD09A1.061 Terra Surface Reflectance 8-Day Global 500	2000—2020	Raster-500m
2	Synthetic Aperture Radar (SAR) Backscatter	Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling	2014—2020	Raster-10m
3	Surface Temperature	MOD11A1.006 Terra Land Surface Temperature and Emissivity Daily Global 1km	2000—2020	Raster-1000m

4	$SO2$ Concentration	Sentinel-5P NRTI SO2: Near Real-Time Surface Dioxide	2018—2020	Raster-1113.2m
5	Administration Data	Database of Global Administrative Areas	-	Vector

2.3 Method

In general, the method in this research begins by collecting the parameters used in the period of 2000—2020, except for backscatter SAR (2014—2020) and $SO2$ concentration (2018—2020). Furthermore, in calculating the Rate of Change calculation, the five parameters are clipped to the mining area boundaries to ensure that calculations are only carried out in the mining area and can be calculated based on time series data, so that the trend magnitude for each pixel is obtained. The final step is to combine the trend results for the five parameters to produce a Mining Activity Index. **Figure 2** shows the flow diagram used in this research.

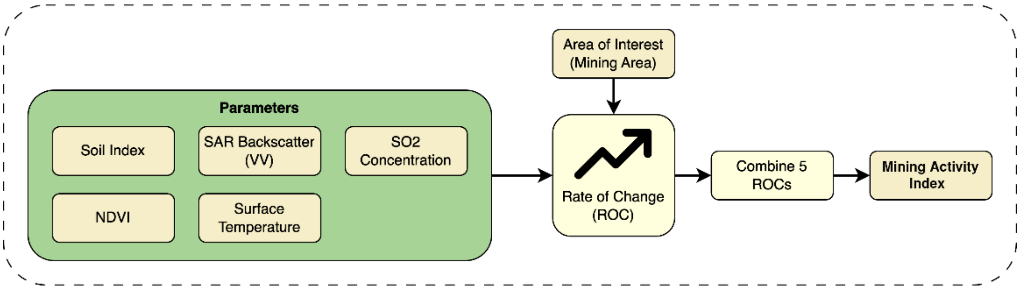


Fig 2. Flowchart used in this research.

3 Result and Discussions

Utilizing remote sensing data integration can be used to assess the impact of mining activities on the surrounding environment. Based on the results of rate of change calculations carried out using time series data for each parameter, it can be seen how the average value changes in units of time or trend. The time span used is 20 years (2000—2020), except for SAR backscatter (VV polarization) and $SO2$ concentration. **Figure 3** presents the results of calculating the rate of change for mining areas in Kalimantan, Indonesia. There are 5 parameters that are used, including Soil Index (SI), Normalized Difference Vegetation Index (NDVI), SAR backscatter (VV polarization), Surface Temperature, and SO_2 concentration.

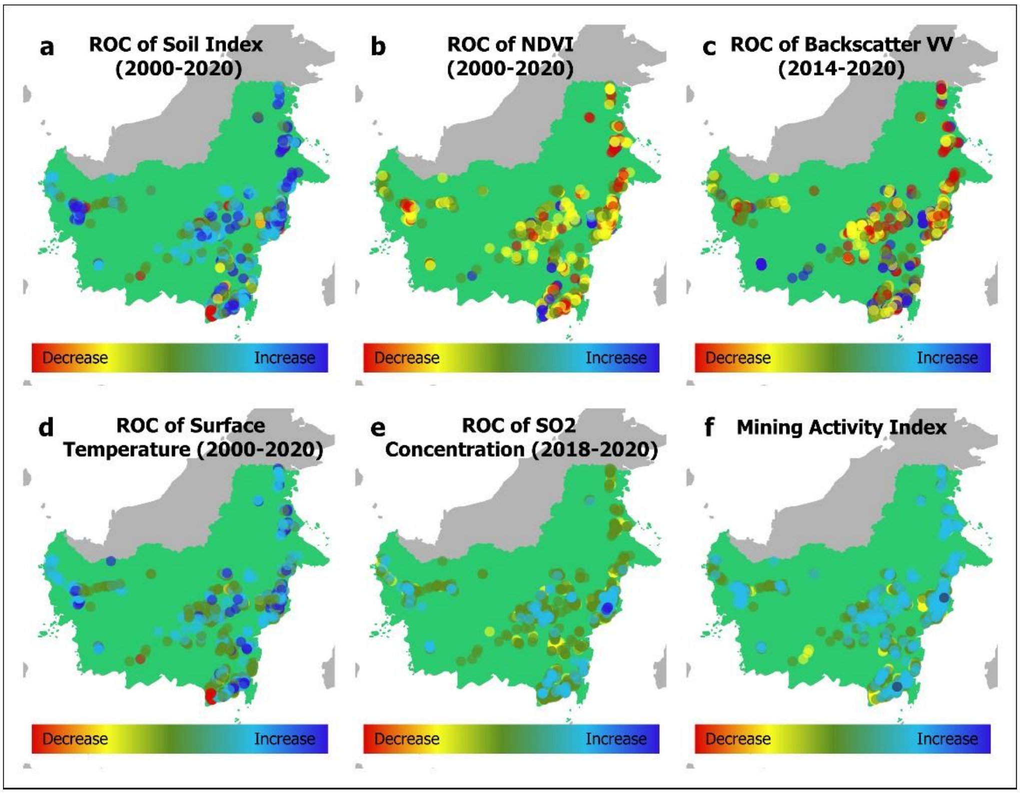


Fig 3. Rate of Change from mining areas in Kalimantan Indonesia with parameters, such as: Soil Index (a), NDVI (b), SAR backscatter VV polarization (c), Surface Temperature (d), SO2 Concentration (e) and a combination of the five ROCs into a Mining Activity Index (f).

First parameter, Soil Index, the increasing trend means that in the span of 20-years there has been a change in the characteristics of the land to open land. **Figure 3a** shows the mining areawith the trend, increasing trend is represented in blue and decreasing trend is represented in red.The higher the Soil Index value indicates the greater the openness of the land, therefore the increase trend can be interpreted as a tendency for land to become open. This land openness could indicate that there are many new mining areas being opened or experiencing area expansion, from 883 mining areas, 400 (45.30%) and 123 (13.93%) of them have high and very high increasing trends. The large number of mining areas reflects the high level of mining exploration and exploitation processes [22].

The second parameter is NDVI, this parameter is related to the previous parameter. **Figure 3b** shows the NDVI trend for each mining area with the increasing trend marked in blue and the decreasing trend in red. With the characteristic that the greater the NDVI value, an area has a greater vegetation density. The decreasing trend in the NDVI parameter means that the mining area in the 20-year period experienced a decrease in vegetation density and vice versa. The results show that most mining areas experience a decreasing trend in red. There are 328 (37.15%) and 70 (7.92%) of the 883 mining areas experiencing high and very high decreasing trends. There is a correlation with the ROC Soil Index value, when the land tends to become open, the vegetation density also decreases. This is also in line with the results of research conducted by [11] that deforestation in Indonesia is the highest in the world with a value reaching 1,901 $km2$ from 2000—2019. Most mining products found in Kalimantan are coal and are usually located underground. To be able to extract the coal, it is necessary to clear the land above the surface or overburden until coal layer is found.

The third parameter is SAR backscatter (VV polarization) which can observe physical characteristics on the surface. **Figure 3c** shows the trend of SAR backscatter (VV polarization) for each mining area, with blue representing an increasing trend and red representing a decreasing trend over a 6-year period. This year range is less than 20 years because the data used is that Sentinel-1 started their operation in 2014. A rough surface will cause the spread of microwave energy in various directions, causing high backscatter values. In contrast, smooth surfaces tend to reflect energy consistently in one direction, resulting in low backscatter. Based on calculations, it was found that most mining areas had a decreasing trend with 406 (45.98%) and 144 (16.31%) of the 883 mining areas experiencing a high decreasing trend. With this information, the decreasing trend in SAR backscatter (VV polarization) shows a tendency for the surface of an area to smooth out. This may be caused by changes in land which was originally forest into open areas as explained in the two previous parameters. The use of these parameters can also strengthen the environmental conditions of the mining area during that period.

The fourth parameter is Surface Temperature, this parameter is used to see whether there is an influence from mining activities on the atmosphere. **Figure 3d** shows the trend over a 20-year period with blue representing an increasing trend and red for a decreasing trend. It was found that most mining areas experienced an increase in temperature with 388 (43.94%) and 83 (9.39%) of 883 mining areas categorized as very high. This increase can be caused by mining activities which can release greenhouse gases and particles which can cause global warming. Apart from that, changes in land cover from initially forest to open land can affect the surface thermal characteristics by direct exposure to sunlight and cause changes in surface temperature. Research by [23] also detected an increase in surface temperature due to mining activities.

The last parameter is $SO2$ (Sulfur dioxide) concentration, this parameter is used to see the effect of mining activities on air pollution. **Figure 3e** shows the trend over a 2-year period with blue representing an increasing trend and red for a decreasing trend. Although the increase in SO_2 concentration can be caused by various activities, one of them can be caused by mining activities. High concentrations of SO_2 can produce acid rain which has the potential to damage nature, such as forests, increase the acidity of soil and water, and even damage ecosystems. Based on calculations, most mining areas have a constant and high trend over a period of 2- years with 643 (72.82%) and 234 (26.50%) respectively. Within this range, it can be interpreted that there is not a very high increase in SO_2concentrations in the Kalimantan mining area. This may happen because the calculations are only carried out in mining areas to extract coal from nature and not in coal burning areas such as steam-based power plants or iron ore smelting areas. When coal is burned or smelted mineral ore, it can produce SO_2. This is in line with research conducted by [24], the results show that industrial mining areas contribute to increasing of SO_2 emissions in a mining area.

Based on the five trends obtained based on the Rate of Change calculation, by integrating these results, a Mining Activity Index can be produced. This model produces mining areas that have characteristics environmental quality decline on the surrounding environment. **Figure 3f** presents the results of the Mining Activity Index and divided into 5 classes, very decrease, decrease, moderate, increase, and very increase. This classification shows that very decrease represents a mining area that has a greater negative impact or environmental quality decline over that period. It can also be interpreted that the quality of the environment is getting worse and vice versa. The results of this integration show that there are 8 (0.91%), 102 (11.55%), 456 (51.64%), 315 (35.67), and 2 (0.23%) for the very low, low, moderate, high, and very high respectively. This shows that there are still many mining areas in Kalimantan that are experiencing environmental damage or have an environmental quality decline.

4 Conclusion

This research conducted an environmental assessment of mining areas in Indonesian Kalimantan using remote sensing approaches. There are 5 parameters used, namely Soil Index, NDVI, SAR backscatter (VV polarization), Surface Temperature, and $SO2$ concentration using the Rate of Change (ROC) method. Based on the calculation results, it was found that the level of damage or decline in environmental quality from mining activity index was around 8 (0.91%), 102 (11.55%), 456 (51.64%), 315 (35.67), and 2 (0.23%) of the total number of mining areas for the very low, low, moderate, high, and very high respectively. With so many mining areas having high negative impacts. This shows that there are still many mining areas in Kalimantan that are experiencing environmental damage or have an environmental quality decline, further steps are needed in the form of strategies to maintain environmental sustainability in the future. This is a challenge for stakeholders to overcome this problem.

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