The NDVI algorithm utilization on the google earth engine platform to monitor changes in forest density in mining area

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Abstract. Periodic forest monitoring needs to be done to avoid forest degradation. In general, forest monitoring can be conducted manually (field surveys) or using technological innovations such as remote sensing data derived from aerial images (drone results) or cloud computing-based image processing. Currently, remote sensing technology provides large-scale forest monitoring using multispectral sensors and various vegetation index processing algorithms. This study aimed to evaluate the use of the Google Earth Engine (GEE) platform, a geospatial dataset platform, in the Vale Indonesia mining concession area to improve accountable forest monitoring. This platform integrates a set of programming methods with a publicly accessible time-series database of satellite imaging services. The method used is NDVI processing on Landsat multispectral images in time series format, which allows for the description of changes in forest density levels over time. The results of this NDVI study conducted on the GEE platform have the potential to be used as a tool and additional supporting data for monitoring forest conditions and improvement in mining regions.

1. Introduction

Forests can be thought of as a mosaic of plant communities that exist within a given landscape. Forest condition information is critical because it acts as the foundation for conserving biodiversity and other natural resources. Forest conditions are collected for various practical reasons, including the collection of forest products, disaster analysis, land use, soil protection, water management, and mining.

Changes in a region's forest cover can result in various changes, including decreased soil fertility, flooding and landslides, erosion, and drought, as well as contributing to global environmental climate change. This is what occurs in areas where a mining business permit has been granted [1]. Mineral-bearing areas are generally designated as protected or conservation forests. For example, one of the largest nickel mining areas on Sulawesi, Vale Indonesia, has a concession area of approximately 71,047.24 hectares, with a portion of the area protected, production, and conservation forest areas. As a result, it will undoubtedly influence the conversion of forested land to mining areas.

Due to the significant impact caused by forest clearing, periodic monitoring of the existing forest is necessary to determine its condition. Additionally, this monitoring must be conducted in areas that have been granted a mining business permit as a way of monitoring a commitment to environmental
restoration. According to Law No. 3 of 2020, mining business license holders are required to conduct reclamation until they achieve a success rate of 100 percent [2]. However, monitoring forest areas mostly through field investigations is expensive and time-consuming, and the results are not always accurate. As an outcome, extensive monitoring of forest conditions is necessary and, therefore, can be conducted at every time. This monitoring technology can be used in combination with remote sensing [3].

Remote sensing is the process and art of acquiring data and information from an object on the earth's surface using a tool that is not directly related to the object being studied [4]. Remote sensing has a variety of applications, one of which is monitoring changes in forest conditions [5,6]. The increasing availability of remote sensing data enables us to monitor forest conditions year after year and compare them to current forest conditions.

With the improvement of remote sensing technology in the provision of satellite imagery, currently, research on forest condition monitoring can utilize these satellite images as a data source. Various types of satellite imagery are available for free and can be accessed by anyone. Several examples include Landsat-8, Sentinel-1, and Sentinel-2. With the development of machine learning systems in image processing, the condition of an area can be detected automatically from the existing image information. One of the features that can be performed is the analysis of the vegetation index; for example, in this study, the vegetation index was analyzed using the normalized difference vegetation index (NDVI).

In this study, an analysis of changes in forest conditions using the NDVI vegetation index was carried out using the Google Earth Engine (GEE) platform [7]. Google Earth Engine is a cloud computing platform for storing and processing large amounts of terrestrial data (data on a Petabyte scale, >1,000 Terabytes). When remote sensing data vendors such as NASA make their image data available to the public through the websites, Google archives them and connects them to publicly accessible cloud computing facilities [8].

With GEE, satellite image processing is no longer done conventionally; downloading and processing, but compiling programming algorithms to instruct the GEE supercomputer to process the data in the desired way. Although an investigation manual (field survey) has proven to be an effective method of obtaining information about the extent of damage and monitoring mine conditions [9], the use of Google Earth Engine (GEE), a geospatial platform, is being tested to improve supervision in evaluating the success of mine reclamation in an effective and accountable way. A manual investigation (field survey) has proven to be an effective method of obtaining information about the extent of damage and monitoring mine conditions, but to improve supervision in evaluating the success of mine reclamation in an effective and accountable way, the use of Google Earth Engine (GEE), a geospatial platform, has been tried out to create a dataset that can combine certain programming algorithms [10].

The use of Google Earth Engine significantly reduces processing time and enables users to process large amounts of previously only possible data with a high-spec computer. Typically, when analyzing temporal data, two images taken at different times are compared. By analyzing this large number of images, a more precise temporal picture can be obtained and a time series of measurements. For instance, this study describes changes in forest density over time in the mining area of Vale Indonesia.

2. Material and methods

2.1. Study area

This research was conducted in the mining area of PT Vale Indonesia Tbk (PTVI), located in the Sorowako Block and administratively located in four sub-districts in East Luwu Regency, namely Malili District, Towuti District, Nuha District and Wasuponda District. This company's concession area is 71,047.24 ha. According to the Decree of the Minister of Environment and Forestry of the Republic of Indonesia No. 362 of 2019 regarding the forest area of South Sulawesi Province, the PTVI is in protected forest areas, limited production forests and conservation areas of 83.59% of the total area and the remaining 16.42% is cultivation area [11]. Due to the size of the area designated as forest in this mining area, it is necessary to monitor the condition of the existing forest, whether used or reclaimed. The location of the research area, which is a Vale Indonesia mining area, is described in detail in Figure 1.
2.2. Remote Sensing Data
The remote sensing data used in this study are from Sentinel 2 (S2) satellite imagery acquired at level 1C in 2015, 2016, 2017, and 2018 and at level 2A in 2019 and 2020. Level 2A S2 image used geometric and radiometric correction BOA (Bottom of Atmosphere) reflectance has been corrected to the point where no further correction is required in this study. However, because S2 level 2A satellite imagery will not be available globally until 2019, the S2 level 1C image used in this study will be corrected using the sensor-invariant atmospheric correction (SIAC) algorithm on the GEE platform [12]. Since 2015, S2 imagery has been available, with a spatial resolution of 10 meters considered capable of assisting forest mapping due to increased temporal resolution and cloud-free image composite quality [13].

2.3. Google Earth Engine Mechanism
Google Earth Engine is an open-source platform for implementing remote sensing applications; this Google product is cloud-based and designed to enable remote sensing studies over extended time scales and spatial extents. Along with data processing, GEE maintains a comprehensive collection of remote sensing data. GEE combines a multi-petabyte catalogue of satellite imagery and geospatial datasets with planet-scale analysis capabilities, making it accessible to scientists, researchers, and developers for the purpose of investigating changes, mapping trends, and quantifying differences in the Earth's surface. The advantage of the GEE platform is that users are relieved from image pre-processing, which requires time and data storage on the user's hardware because the database and computing processes are cloud-based.

Users are not required to have the latest computers or software, which means that researchers in less developed countries can access the same software and analytical capabilities as those in developed
countries [8]. This research utilizes GEE processing capabilities and Sentinel image archives to monitor forest conditions. In conclusion, the GEE work process being analysed is a combination of satellite imagery availability and programming algorithms applied to monitoring forest conditions.

![User Interface Platform Google Earth Engine](https://code.earthengine.google.com/d1026f174590f2553bfd91af1af5e13d)

**Figure 2.** User Interface Platform Google Earth Engine. (https://code.earthengine.google.com/d1026f174590f2553bfd91af1af5e13d)

2.4. **Data processing**

Data processing in this study is divided into three stages: preparation, processing, and analysis. The stages of the research are depicted in Figure 3.
The first stage of this research is preparation and data collection. At the preparation stage, a reference review is carried out regarding the method to be used. The data collection process, specifically collecting data required for research and used in this study, is secondary data from S2 images. The processing stage of this research uses the javascript programming language. The processing stage includes entering the S2 image data and the Vale Indonesia concession area boundaries into the GEE, which will be used to cut the S2 image for use. Additionally, cloud masking is applied to the image in order to remove clouds that cover the study area.\[14\].

The Normalized Difference Vegetation Index (NDVI) algorithm is used to transform the vegetation index. The bands used in the calculation in the S2 image are band 8 (nir) and band 4 (red), both of which have a spatial resolution of 10 meters. The NDVI value is calculated by dividing the difference in normalization between the red and near-infrared bands by the number of bands in the image. The formula for developing the NDVI algorithm is as follows [4]:

$$\text{NDVI} = \frac{\rho_{\text{nir}} - \rho_{\text{red}}}{\rho_{\text{nir}} + \rho_{\text{red}}}$$

Where:
\(\rho_{\text{nir}}\) : NIR band reflectance value
\(\rho_{\text{red}}\) : RED band reflectance value

The NDVI index value ranges from -1 (no vegetation) to 1 (vegetation). Research has indicated that an NDVI index value mostly less than 0.3 indicates an unvegetated area, while a value greater than 0.6 indicates dense vegetation \[15–17\]. The table below shows the distribution of index values used in this study to determine the density and greenness of vegetation in the study area.
Table 1. Vegetation Index Value Range.

| Code | Index  | Classification       |
|------|--------|----------------------|
| 1    | -1.0-0.3 | Non-Vegetation     |
| 2    | 0.3-0.5  | Shrubs               |
| 3    | 0.5-0.6  | Low Density Forest  |
| 4    | 0.6-0.7  | Moderate Density Forest |
| 5    | 0.7-1    | High Density Forest |

Source: Modification of Vision of Technology [18]

Annually, the classification results will be used to calculate the area of each classification. The final stage presents all the findings from the analysis of the distribution of changes in forest density across Vale Indonesia's mining areas.

3. Result and discussion

From the results of processing NDVI S2 satellite imagery data on the GEE platform in 2015-2020, 5 land cover classes in the Vale Indonesia mining area were obtained, namely non-vegetation, shrubs, low density forest, moderate density forest and high-density forest. The distribution is presented in Table 2 and Figure 4 below.

Table 2. Changes in Forest Density Conditions from 2015-2020 in Vale Indonesia Mining Areas.

| Year | High density forest | Moderate density forest | Low density forest | Shrub | Non vegetation | Cloud |
|------|---------------------|-------------------------|--------------------|-------|----------------|-------|
| 2015 | 2,377.37            | 16,798.09               | 9,557.10           | 8,293.91 | 14,627.21 | 19,551.31 |
| 2016 | 25,302.50           | 24,093.36               | 11,033.69          | 5,998.07 | 4,777.13   |       |
| 2017 | 20,555.02           | 29,969.70               | 11,481.14          | 7,108.67 | 2,090.90   |       |
| 2018 | 15,975.87           | 38,965.21               | 9,475.59           | 2,874.06 | 3,914.70   |       |
| 2019 | 2,259.23            | 46,018.43               | 13,187.77          | 5,632.05 | 4,107.68   |       |
| 2020 | 1,992.63            | 44,210.87               | 15,000.85          | 5,884.63 | 4,116.25   |       |
As shown in Table 2 and Figure 4, the area of forest density has changed in Vale Indonesia's mining area, with high density forest generally declining and being replaced by moderate density forest or shrubs and non-vegetation (mining openings). However, if you examine the data from 2015, you will recognize that several areas are missing due to the influence of a large cloud. This is because the new Sentinel satellite was tested in that year. Between 2016 and 2020, it is becoming clear that this image has the capacity to accurately depict the state of forest density in each area. Between 2016 and 2020, a change in forest density is observed. This is also supported by the declining average value of the NDVI index in the Vale Indonesia mining area, as illustrated in Figure 5 below.

Figure 4. Map of Forest Density Changes in Vale Indonesia Areas for (a) 2015, (b) 2016, (c) 2017, (d) 2018, (e) 2019, and (f) 2020.
As illustrated in Figure 5, the level of forest density has decreased year after year, as indicated by a decrease in the NDVI index value. Each year, the index value decreases by 0.05. The GEE platform, combined with the availability of Sentinel catalogue data, is extremely beneficial for monitoring forest conditions, particularly in areas designated as forest areas and granted area utilization permits. With this technology, it is possible to save time, money, and effort while obtaining results quickly.

4. Conclusions
The NDVI analysis results obtained through the Google Earth Engine platform have the potential to be used as a tool and additional supporting data for monitoring changes in forest conditions over time. It requires extensive additional testing of the Google Earth Engine application by comparing NDVI values to field conditions to obtain more accurate data.

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