Analysis vegetation change on coal mine reclamation using Normalized Difference Vegetation Index (NDVI)

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Abstract. Vegetation cover is a critical indicator and sensitive in degradation land. This study aims to explore the comparative analysis of vegetation index in the ex-mine reclamation area. The study is conducted on 2.03 ha area reclamation planted in 2017. The analysis is performed by measure Normalized Difference Vegetation Index (NDVI) from 2017 to 2020 using the Sentinel-2 satellite imagery dataset and processed by ArcGIS Pro 2.6 software. RGB drone photogrammetry acquired in April 2020 and vegetation photos featured with geotagging is used to validate vegetation index analysis. The result shows NDVI first and second-year revegetation demonstrates no significant improvement (less than 0.33), nevertheless third and fourth-year revegetation shows dramatically increase of NDVI, respectively 0.369 and 0.417 with the percentage of healthy vegetation 68.13% and 81.39%. This shows that NDVI and the percentage of vegetation health improve over the year.

1. Introduction

Coal mining activities are still considered to support both the energy and economy of Indonesia [1]. The growth in the number of coal production followed by a disturbed area significantly. However, this is also followed by the increase of reclamation progress considerably at 16% in 2019 compared by the previous period 2013-2018 average at 2% per year [2]. The issues of mining activities have received considerable critical attention. Surface mine activities unavoidably change land use. Besides may impact the land surface, air pollution, sedimentation, and negative aesthetics [3], however, the objective of the mine reclamation is to organize, restore and repair the quality of the environment and ecosystem to return to the initial functions [4] and satisfying environmental regulator [5]. Reclamation is related to land use planning; the impact of land degradation can be reduced by selecting an appropriate method. Restore the disturbance land immediately is the best choice; often, no natural recovery of disturbed land can occur than natural succession [5] [6].

The previous research states that the mine reclamation meets successful criteria regulated in the Ministry of Energy and Mineral Resources (MEMR) regulation in six years [7]. The research conducted on the reclamation area in 30 coal mine companies, the data taken from 2008 to 2017, demonstrates 35.63% meet successful criteria in the sixth-year plantation. However, the study base on reporting and field assessing visually. Considering the study, the spatial method using vegetation index is needed to analyze vegetation quality measurably.

The vegetation index is a crucial biological physical indicator for assessing environmental change in degraded lands [8] [9]. Analysis of vegetation change can be obtained through monitoring the vegetation
cover [10]. Many researchers have used vegetation indices to measure mine reclamation revegetation [6] [10] [12]. Normalized Difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), and Enhanced Vegetation Index (EVI) are usually used to determine vegetation index while the most popular tools and practices for monitoring and assessing index vegetation health commonly using NDVI [13].

This study aims to show the progress of vegetation quality over time through NDVI calculation comparatively. The method uses analysis NDVI time series and classifies vegetation health base on vegetation index. The research location is conducted on a coal mining company located in South Kalimantan Province, Indonesia. This location is planted in 2017 with various vegetation of cover crops, pioneer, and local species.

2. Method

2.1. Study area

This study is performed on the ex-coal mine reclamation area located on Tanah Bumbu Regency, South Kalimantan Province, Indonesia. The area lies between coordinates 115°37'56"E - 115°38'3"E and 3°36'2"S - 3°35'46"S as shown in Figure 1. This location has a 2.03 ha area and reclaimed since 2017 with a cover crops, pioneer dan local species shown in Table 1.

Table 1. Vegetation species.

| Vegetation | Species | Remarks |
|------------|---------|---------|
| Cover crop | Centrosema pubescens (CP), Calopogonium mucunoides (CM), Pueraria javanica (PJ) | Space 4 x 4 m, 625 trees/ha |
| Pioneer    | Paraserianthes falcataria | |
| Local      | Mangifera indica (mango), Eucalyptus deglupta (eucalyptus), Artocarpus heterophyllus (jackfruit), Artocarpus champeden (cempedak), Swietenia macrophylla (Mahogany), Shorea Sp. (Shorea) | Total of 525 trees |

Figure 1. Reclamation on the mining area.
2.2. Data processing and analysis
A dataset covering the period 2017-2020 collected from Sentinel-2 satellite imagery shows in Table 2. All imagery datasets are downloaded from the U.S Geological Survey database (https://glovis.usgs.gov) and selected with less than 10% cloud coverage. The dataset is processed using ArcGIS pro 2.6 software to calculating the Normalized Difference Vegetation Index (NDVI) and classify vegetation health.

Table 2. Satellite Imagery Dataset [14].

| Imagery | Sentinel-2 |
|---------|------------|
| Band    |            |
| Spectral B1: 0.443 |
| Spectral B2: 0.443 |
| Spectral B3: 0.490 |
| Spectral B4: 0.665 |
| Spectral B5: 0.705 |
| Spectral B6: 0.740 |
| Spectral B7: 0.783 |
| Spectral B8: 0.842 |
| Spectral B8a: 0.865 |
| Spectral B9: 0.940 |
| Spectral B10: 1.375 |
| Spectral B11: 1.610 |
| Spectral B12: 2.190 |
| Spatial Resolution | |
| 10 m (Spectral B2, B3, B4, B8) |
| 20 m (Spectral B5, B6, B7, B8a, B11, B12) |
| 60 m (Spectral B1, B9, B10) |
| Acquisition | |
| 2017: 16 April 2017 |
| 2018: 04 April 2018 |
| 2019: 04 April 2019 |
| 2020: 05 April 2020 |
| Map projection | UTM 50S, Datum WGS84 |

The Sentinel-2 bands are processed to calculate NDVI. RGB band (B4, B3, B2) and spectral band (B8) are composited to make natural color and calculation vegetation index. NDVI may be calculated from the equation below:

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

(1)

where:
NIR = near-infrared band reflectance value
Red = red band reflectance value

The value of NDVI constantly -1 and +1, vegetation value commonly has positive NDVI with range 0.2-0.8 and negative value does not show any vegetation [8]. The geotagging photos taken on June-July 2020 are collected to shows vegetation quality. The photos are chosen a range of NDVI values.

3. Results and discussion
3.1. NDVI development

NDVI time series need remodeling to provide more reliable sequential data, besides, to set truly reflect the variation trend of vegetation NDVI [8]. In the first year of reclamation (Figure 3.a dan Figure 3.e), NDVI distribution shows a range of 0.04-0.32 and mean 0.087 that indicates this area has just revegetated (this indication base on observation from another reclamation location that planted on March 2020 and supported using geotagged photos acquisition on 20-26 July 2020 shown in Figure 2.a and 2.b, photo drone acquisition on 20 June 2020 shown in Figure 2.c and satellite imagery Sentinel-2 acquisition on 04 June 2020 shown in Figure 2.d). Vegetation growth begins showing the progress on the second year reclamation with NDVI range 0.08-0.35 (Figure 3.b) and mean 0.21 (Figure 3.f). However, still dominated by vegetation with a low NDVI range 0.17-0.19. The third-year reclamation shows significant NDVI distribution of 0.14-0.62 (Figure 3.e) and mean 0.37 (Figure 3.g) and dominated by vegetation with the NDVI range 0.36-0.39. This range almost twice compares to the second-year reclamation. The fourth-year reclamation NDVI distribution has a range of 0.04-0.65 (Figure 3.d) and a mean of 0.42, dominated by the NDVI range of 0.41-0.49 (Figure 3.h).

![Figure 2. Geotagged photos of revegetation in another location.](image)
The graph from Figure 3.i shows the development of the NDVI time series period 2017-2020. What can be seen in the graph is the continual growth of the mean vegetation index (NDVI). NDVI value for vegetation range usually from 0.2-0.8 [8], from the graph, the mean NDVI value at the first-year plantation (2017) shows very low while in the second-year reclamation (2018) demonstrates a sharp increase in the number of mean NDVI however still classified as the low index. The rise relatively high in the mean NDVI begins in the third year (2019) and fourth year (2020), respectively 0.369 and 0.417.

3.2. Percentage analysis of vegetation growth
The previous study [10] monitoring vegetation cover in the reclamation area using vegetation health indices is an effective method; moreover, NDVI shows the best indicator for vegetation health monitoring than RVI, EVI. In this study, NDVI is classified into four criteria (Table 3), non-vegetation, unhealthy, healthy, and very healthy. The classification base on the range of vegetation index that indicates vegetation health.
Table 3. NDVI Classifications [15].

| Indication           | Vegetation Index |
|----------------------|------------------|
| Non-vegetation       | <0               |
| Unhealthy vegetation | 0.01-0.33        |
| Healthy vegetation   | 0.33-0.66        |
| Very healthy vegetation | ≥0.66          |

From Figure 4.a, the first year reclamation dominated unhealthy vegetation coverage at 99.7%. In this case, unhealthy vegetation shows that vegetation has just been planted. No significant difference in the second year revegetation shown in Figure 4.b and Figure 4.e still dominated unhealthy vegetation with a percentage of 96.03% and a small portion of healthy vegetation 3.2%. On the third-year progress, the healthy vegetation index shows dramatically increased at 68.13% (Figure 4.c and Figure 4.e) compare to second-year reclamation. The fourth-year healthy vegetation slightly increases with a percentage of 81.39% (Figure 4.d and Figure 4.e).

![Figure 4. Vegetation health from 2017-2020](image-url)
The field vegetation photos featured geotagging coordinate taken to validate vegetation quality. The photos are taken from June–July according to NDVI and vegetation class coordinates of the reclamation area 2020. The photos show in Figure 5.b are taken on 20 July 2020 located with NDVI 0.28. The photo represents the unhealthy vegetation range. We can analyze the area that shows vegetation growth, not evenly, and founded the barren area. However, healthy vegetation is represented in Figure 5.c (taken at 20 July 2020) and Figure 5.d. (taken at 4 June 2020) with NDVI respectively, and at a level of 0.52 and 0.64 shows evenly.

Classification NDVI through the pixel base technique has effectiveness in describing vegetation growth. This study has shown changing the phenology of vegetation over time and verified through field geotagged photos. The success of reclamation is characterized by a high value of vegetation indices [10]. These findings indicate vegetation growth improving over time and vegetation health class dominate at the third and fourth year planting.
4. Conclusion
This study has identified that vegetation on the first and second-year plantation shows no significant NDVI and is classified as unhealthy vegetation (less than 0.33). However, on the third-year reclamation, increasing, undoubtedly, mean NDVI 0.369 and healthy vegetation percentage reach 68.13%, followed by an increasing mean NDVI in the fourth year at 0.417 growth percentage reach 81.39%. The analysis data found that NDVI and the percentage of vegetation health increase over the year. This study supports the idea that classification vegetation health through NDVI calculations has effectiveness in describing vegetation growth. Besides that, this study makes several contributions to the current literature. First, to support analysis for the current reclamation monitoring method in Indonesia. Second, assessing successful reclamation becomes measurable. Third the further study with more year span, different vegetation species characteristics and location can be modeled to predict reclamation period to meet successful criteria reclamation in Indonesia.

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