Natural colonization of vegetation under twenty years restoration of ex-cement mining

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Abstract. Biodiversity loss can be drastically aggrivated by mining activities. Opened pit mining removes all material, including vegetation, above the ore deposit. Cement industries always implement opened mining as they process all rocks into cement. Restoration is known as the best human interference to drive the damaged ecosystem to recover. This study aimed to observe vegetation that was naturally grown under Pinus sp after 20 years of planting on ex-cement mining. The study was conducted in Sukabumi District, in three sites that were distributed in Cicantayan (2 sites) Sub District and Cibadak Sub District. Each location was divided into three points to conduct analysis vegetation in transects, for trees 2 units (10 x 10 m), shrubs 4 units (5 x 5 m), and grasses 5 units (1x1 m). The study resulted after 20 years of planting with Pinus (3 x 3 m) the sites recorded have been inhabited by 13 new species. They are 4 woody trees species, 4 species of shrubs, and 5 species of under-story (grasses). Tree stratum new inhabitants are Ficus spp, Macaranga gigantea, Schima wallichii, and Hibiscus tilliaceus, with the important value index (IVI) 57.83%; 53.67%; 33.17 %, 26.5%; respectively. Shrub’s stratum is inhabited by Mimosa invisa (IVI 76.66 %); Eupatorium odoratum (IVI 76.66 %); Melastoma malabathricum (IVI 73.83 %); and Clibadium suninamensis (IVI 72.83%). Whereas grasses stratum inhabited by Imperrata cyllindrica (IVI 98.77 %); Brachiaria decumbens (IVI 98.60 %); Themedia gigantea (IVI 43.11 %); Setaria spp (IVI 31.83 %), Cymbopogon citratus (IVI 27.69 %). Shortly, restoration has encouraged natural colonization even acid mine drainage on the body waters remains occurred.

1. Introduction
In Indonesia, the mining sector is one of the most important economic pillars. Mining activities are mainly conducted in four ways, underground, open surface (pit), placer, and in-situ mining [1]. However, underground and open surfaces are among the most applicable in Indonesia. Underground mines are more expensive and are often used to reach deeper deposits, while surface mines are typically used for more shallow and less valuable deposits [1]. Open mining techniques are recognized as the most hazard to the biodiversity lost because it removes all layers above the parent rock, included all vegetation [2]. Surface mining is frequently driving to acid mining drainage (AMD) phenomenon, as the parent rock contains sulphidic elements exposed to oxygen and water, then releases sulfate to the environment [2]. In Indonesia, where rock formations are determined by volcano activities, AMD incidents are found almost at all opened mining activities.
Cement is one of the most vital materials for all infrastructure developments in Indonesia. Annual production for domestic and export in 2020 is 115 million tons. The raw material of cement industries is lime rocks and clay. The raw material of cement industries consists of four components that is lime rock, clay, iron sand, and silica sand. They are collectively called quarry. Cement industries apply an open surface technique as this factory needs to process all rocks into a mixed powder known by all consumers as cement.

After mining enclosure, the companies responsible for accomplishing restoration activities as mandated in the Government Regulation no. 78/2010 on Reclamation and Post Mining. Successful ex-mining reclamation is characterized by plant growth satisfactory, the minimum survival rate is 80%, sufficient population of each hectare, and suitable plant combination and health [3]. Whereas Claassen et al. (2008) stated, one of the indicators of reclamation success is the presence of vegetation naturally [4]. Perrow & Davy (2002) explained plant species composition and richness as criteria for evaluating the success of restoration [5]. This study is aimed to observe the performance of vegetation composition under Pinus plantation after 20 years of ex-cement mining site reclamation. The result, hopefully, can be illustrated to study the success story of vegetation during the 20 years due to the human intervention.

2. Material and method

The study is located in Sukabumi District of West Java. There are three sites, at the Sub District of Cibadak (1 site) and Cicantayan (2 sites). Sites at Cicantayan (540 m above sea level) are involved as Cicohag and Cicantayan Villages, whereas Cibadak (606 m above sea level) site is managed as Renzo Edu Park. The study is carried out in the transect method for vegetation analysis. The plot size of the outset is 10x10 m edged with a colored line; it purposes for tree strata. The outset plot was then divided into four plots sized 4x4 m for shrubs stratum and into eight plots sized 1x1 m for grasses stratum. Sample observations were carried out at 1 plot for trees, 2 for shrubs, and 5 for grasses at each outset plot. Trees excluded Pinus spp were calculated (canopy and stem diameter, species name, total number); shrubs and grasses were calculated the total number and species name [6].

2.1. Species importance value index (IVI)

Data collected then were calculated to find the importance value index (IVI) to illustrate the domination of each species in their ecosystem. IVI comes from the complementation of Relative Frequency (RF), Relative Density (RS), and Relative Dominance (RD).

To observe the composition and structure of vegetation data will be calculated as the following equation de la Maza et al. (2002) [7]:

Species Density (S) = \( \frac{\text{total of species individual}}{\text{square plot unit}} \)  

Species Frequency (F) = \( \frac{\text{total of species individual at each plot}}{\text{total number of plots}} \)  

Species Dominance (D) = \( \frac{\text{basal area square plot}}{\text{}^2} \)  

Relative Density (RS) = \( \frac{\text{density of a species}}{\text{Total of density}} \times 100\% \)  

Relative Frequency (RF) = \( \frac{\text{frequency of a species}}{\text{Total of frequency}} \times 100\% \)  

Relative Dominance (RD) = \( \frac{\text{dominance of a species}}{\text{total of dominance}} \times 100\% \)
IVI = RS + RF + RD  

(7)

2.2. Biodiversity index

Species diversity is the most important parameter for comparing between two communities, particularly to study the impact of biotic disturbance, level of succession, or ecosystem stability. Species diversity counted with the following equation of Shannon-Wiener.

\[
H' = \sum_{k=0}^{n} \left( \frac{n_i}{N} \ln \left( \frac{n_i}{N} \right) \right)
\]

(8)

Where:  
- \( H' \) = Biodiversity index of Shannon – Wiener
- \( n_i \) = total number of species found in the \( n^{th} \) stratum
- \( N \) = Total number of species

2.3. Species richness index (Margaleff)

This index is useful to observe the species richness in an area of the ecosystem, which can be calculated by the following equation [8]:

\[
R = \frac{s}{\ln(N)}
\]

(9)

Where:  
- \( R \) = Species richness index of Margaleff
- \( S \) = Total number of species
- \( N \) = Total number of species individual

3. Result and discussion

Inventory of vegetation activities at the sites found 13 species plants emerge following the 20 years of \textit{Pinus} spp plantation. Table 1, 2, and 3 illustrated emerging species compose three strata of vegetation; that are tree stratum (4 species), shrub stratum (4 species), and herb/grasses stratum (5 species).

| Species              | RF    | RD    | IVI (%) |
|----------------------|-------|-------|---------|
| \textit{Macaranga gigantea} | 0.676667 | 1.570 | 53.6667 |
| \textit{Pinus} spp*  | 1.000000 | 2.198 | 128.8333 |
| \textit{Ficus} spp  | 0.333333 | 3.140 | 57.8333 |
| \textit{Schima walachia} | 0.333333 | 1.570 | 33.1667 |
| \textit{Hibiscus} spp | 0.333333 | 0.942 | 26.5000 |

After 20 years of re-vegetation activities with \textit{Pinus} spp 3 x 3 m, it is found at the tree stratum, four species grew spontaneously. Considering the IVI \textit{Pinus} spp (128.83) (Table 1), it can be stated that \textit{Pinus} spp successfully plays an important role as the ecosystem engineer in the study site, which is a bare land from the ex-cement mining. IVI of a species is one of parameter demonstrated the role of this species in their community. The presence of a species in an ecosystem shows adaptability and tolerance to most environmental conditions. IVI of a species is in arrange 0-300. The value demonstrates role of a species in dominating the ecosystem [7]. In this study \textit{Pinus} plantation facilitate \textit{Ficus} spp, \textit{Macaranga gigantea}, \textit{Schima walachii}, and \textit{Hibiscus} spp to colonize the ex-cement mining. The four species are involved in pioneer. Among the four new tree species, \textit{Ficus} spp seem to be the most adaptive (IVI = 57.833%), followed by \textit{Macaranga gigantea} memiliki (IVI = 53.667%); \textit{Schima walachii} (IVI = 33.167%)}
and Hibiscus spp (IVI = 26.500%). Correspondingly, the species IVI indexes then use for calculating Margalef’s biodiversity index (H’). In this study, tree stratum has H’ by 1.028624; H maximum by 1.609438, evenness index by 0.63912, and species richness index by 1.24267. It means that the study sites still have a poor biodiversity after 20 years of re-vegetation. Referring to Boontae et al (1995), the value of R is in arrange of 3.5-5.0; when R1 < 3.5 the site is categorized has a poor species richness; when 3.5 < R1 <5.0 is categorized as moderate; while if R1 > 5.0 the site is categorized has a high species richness [8]. The poor biodiversity in this study perhaps caused by the narrower plot experiments (10 x 10 m), because another study by Komara et al (2016) using 20 x 20 m plots has a richer biodiversity only after 16 sixteen years of revegetation [9]. It due to Margalef index value will be higher when the sample plot is set up to be larger, as well as, when the site has a higher biodiversity index [8].

Table 2. Shrubs stratum important value index

| Species              | FR   | DR   | IVI (%)   |
|----------------------|------|------|-----------|
| Mimosa invisa        | 1.000000 | 0.1884 | 76.66544  |
| Melastoma malabathricum | 1.000000 | 0.2512 | 73.83143  |
| Eupatorium odoratum  | 1.000000 | 0.1884 | 76.66544  |
| Clibadium surinamensis | 0.666667 | 0.1884 | 72.83769  |

The second stratum, shrubs, it is found four species which spontaneously grow after 20 years re-vegetation activities (Table 2). Among the four, Mimosa invisa and Eupathorium odoratum are the most dominant. They have the same IVI (76.665 %), then followed by Melastoma malabathricum (IVI = 73.831%), and Clibadium surinamensis (IVI = 72.837%). Dissimilar to Eupathorium odoratum, which has a large coverage, Mimosa invisa has thin coverage. However, it is able to construct symbiosis with rhizobium to fix atmospheric nitrogen. According to the calculation, the shrub stratum has biodiversity index (H’) by 1.358; H maximum by 1.386; evenness index by 0.980, and species richness index by 1.019, which is categorized as poor. That is similar to the tree stratum.

Table 3. Grasses stratum importance value index

| Species              | FR   | DR   | IVI (%)   |
|----------------------|------|------|-----------|
| Themedia gigantea    | 1.000000 | 0.1256 | 43.11406  |
| Brachiaria decumbens | 1.000000 | 0.1884 | 98.59675  |
| Imperrata cylindrica | 1.000000 | 0.1884 | 98.76783  |
| Cymbophogon citratus | 0.333333 | 0.1570 | 27.69497  |
| Setaria spp          | 0.333333 | 0.1884 | 31.82639  |

The presence of herbaceous plants benefits the reclamation program through their role as ground cover [9]. After 20 years of re-vegetation with Pinus spp, in the sites can be found five species of herbaceous plants stratum. The highest IVI found to belong to Alang-alang or Imperrata cylindrica (98.767%), followed by Brachiaria decumbens (98.596 %), Themedia gigantea (43.114%); Setaria spp (31.826 %), and Cymbophogon citratus (27.694 %); respectively. It can be understood that alang-alang is the most aggressive pioneer of weed. However, in this situation, their presence can be a benefit to the environment, especially their service as microclimate engineers. Similar to the other strata, the biodiversity index of the herbaceous stratum is also categorized as poor (H’ by 0.778; H maximum by 1.609; evenness index by 0.483, and species richness index by 0.566).

The comparison of vegetation colonization is sketched in Figure 1. During 20 years, the ex-cement mining ecosystem shows complete strata of vegetation. However, the weakness of the study is no available data demonstrated the stages of the progress. The ability of plants to grow in the reclamation site can be attributed to seeds already present in the top soil during the reclamation process or by seed dispersal [9]. Based on the number of plant species that successfully grew at the reclamation site, the
following finding could be used to suggest further management of this study site. In terms of species richness, it can be enriched with some local multi-purpose’s species.

![Figure 1](image_url)

**Figure 1.** Sketch of comparison among the early reclamation stage and after 20 years.

4. **Conclusion**
Mining activities are firmed as the hardest disturbance to biodiversity loss. After 20 years of reclamation, the site is still in poor biodiversity and species richness. The site has a good condition; however, without sufficient maintenance, *Pinus* spp plantation successfully facilitate 13 other species to grow spontaneously. The new emerging species constructed three strata of vegetation in the ecosystem.

**Authorship contribution**
All authors have equal contributions during the field activities, data analysis, and draft of this manuscript. Hence, there is no co-author in this study.

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