JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 9, Number 1 (October 2021):3201-3210, doi:10.15243/jdmlm.2021.091.3201
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

The possibility of reclamation criteria success in Indonesia: soil condition, vegetation structure and species composition

Tedi Yunanto[1*], Farisatul Amanah[2], Nabila Putri Wisnu[1]

[1] Bandung Polytechnic of Energy and Mining, Ministry of Energy and Mineral Resources, Jl. Jenderal Soedirman No. 623, Bandung, Indonesia 40211
[2] Directorate General Mineral and Coal, Ministry of Energy and Mineral Resources, Indonesia, Jl. Prof. Dr. Soepomo, S.H. No. 10, Jakarta, Indonesia 12870

[*]corresponding author: tedi.yunanto@esdm.go.id

Article history:
Received 18 August 2021
Accepted 21 September 2021
Published 1 October 2021

Keywords:
mining
reclamation criteria
soil condition
species composition
vegetation structure

Abstract

There are two regulations for mine reclamation success in the forestry area in Indonesia, namely Minister of Forestry Regulation No. P.60/Menhut-II/2009 and Minister of Energy and Mineral Resources Decree No. 1827.K/30/MEM/2018. Both regulations rule vegetation and soil success. This study aims to analyse criteria parameters from both regulations in the mine reclamation and compare them to the surrounding secondary natural forest (SNF). This study was conducted in 6 six types of mine reclamation stand structures: 1, 4, 6, 9, 11-year-old plantation and SNF using 1 hectare of the circular plot each (total 6 ha). Soil samples were collected from 40 cm depth to analyse physical, biological and chemical conditions. Mine reclamation areas had almost similar physical, biological and chemical soil conditions with SNF. Nevertheless, due to the potential acid-forming (PAF) material from overburden, the 1-year-old plantation had pH = 3.23-3.27. The highest diversity index and the number of species and families in all reclamation areas were H' = 1.82 (11-year-old); 14 species (9-year-old); and 11 families (9-year-old), comparing with SNF were H' = 3.48; 67 species, and 31 families. Conversely, vegetation structure parameters in mine reclamation areas were higher than SNF (diameter at height breast (DBH; 1.3 m) = 28.42 cm; tree density = 469/ha; basal area = 35.04 m^2/ha; and total height = 16.85 m). Compared to the SNF, vegetation structure and soil conditions are mostly possible for mine reclamation success. Still, species composition needs to be considered further as a standard interval to meet the criteria.

To cite this article: Yunanto, T., Amanah, F. and Wisnu, N.P. 2021. The possibility of reclamation criteria success in Indonesia: soil condition, vegetation structure and species composition, Journal of Degraded and Mining Lands Management 9(1):3201-3210, doi:10.15243/jdmlm.2021.091.3201.

Introduction

As a developing country, Indonesia relies on natural resources such as coal for domestic income. Open-pit mining methods are widely used in Indonesia (Yunanto, 2018). Coal extraction with open-pit mining method gives adverse effects on the environment such as reducing the biodiversity of both flora and fauna (Lloyd et al., 2002; Slingenberg et al., 2009), soil characteristic alteration (Subowo, 2011) and create a wide, deep hole (void) (Doupé and Lymbery, 2005). A mine reclamation program is mandatory to reduce the impacts. According to Minister of Energy and Mineral Resources (MEMR) Decree No. 1827.K/30/MEM/2018, mine reclamation is an activity to restore and improve the quality of the environment and ecosystem ex-mining area in accordance with the land use during the mining operations phase. Typical forms of mine reclamation are forest, housing, plantations and tourism object. In addition, mine reclamation bonds must be placed and released after annual government evaluation. However, since mining is allowed to be carried out in forest areas, Minister of Forestry (MF) Regulation No. P.60/Menhut-II/2009 regulates that restoration is only an option. Therefore, there are two rules for reclamation success in the forestry area: MF Regulation No. P.60/Menhut-II/2009 and MEMR Decree No.1827.K/30/MEM/2018. In general, both regulations rules soil and vegetation aspects.

In association with mine reclamation bonds, an annual implementation report has to be submitted to the government. Reports are evaluated on sites due to success assessment. After the assessment, the percentage of success is used to release the bond. The remaining bond is placed back and evaluated in the following year until 100% success is achieved. Meanwhile, mining in forest areas also requires watershed rehabilitation and non-tax revenue payment. The assessment by MF is also used to release the non-tax revenue obligation. Thus, mine reclamation is very influential on the finances of the coal company.

Mine reclamation encourages natural succession. Succession consists of several stages, in which each stage creates a favourable condition in the next stage (Martin and Gower, 1996). Mining in forest areas makes total clearance of plants and soil. Mine reclamation is one form of the primary succession process, as it aims to restore the forest to the original in a very long time. The key to the success of mine reclamation is an understanding of strategies to comply with success based on regulations and reclamation/vegetation growth (succession). This study aims to find the reliable parameters that can be met in both regulations by comparing the situation in secondary natural forests (SNF) around mining companies.

Materials and Methods

Study area

The study was conducted in the reclamation area and SNF around PT Mahakam Sumber Jaya, Kutai Kartanegara Regency and Samarinda City, East Kalimantan Province, Indonesia. A vegetation inventory and soil sampling was conducted in six stand types: the one-year-old (1-yr-old) plantation (reclamation 2015), the four-year-old (4-yr-old) plantation (reclamation 2012), the six-year-old (6-yr-old) plantation (reclamation 2010), the nine-year-old (9-yr-old) plantation (reclamation 2007), the 11-year-old (11-yr-old) plantation (reclamation 2005) and the SNF near reclamation 2012 for comparison (Figure 1).

Data collection and analysis

Soil samples were collected in each stand of five sample points with 0-40 cm in depth (a total of 30 soil samples for six stand types). The samples were taken near the tree roots. The plot design was a square plot with a radius of 50 m at each point. Four samples were taken from the corners of the square and one sample in the centre of the plot (Figure 2).

The study for soil cover was conducted using a box-shaped sieve with a size of 1m x 1m and a rectangular box inside with ± 6.3cm x 6.3cm in size. Measurement and calculation of the number of cover crops filtered on the box are were conducted at five points in each circle on the south, north, west, east and middle of the plot (Figure 3). While the measurement of canopy cover was conducted using a densiometer collected in the same area as soil cover. Vegetation inventory was conducted using a modified circular plot method with r = 17.8 m or ± 0.1 ha (James and Shugart, 1970). Ten plots were applied as the minimum plot in the silviculture study (Lamprecht, 1989) for each vegetation/stand type in mine reclamation areas (1, 4, 6, 9, and 11-yr-old plantation) and SNF (Figure 1). Therefore, the total of plots were 60 plots or ± 6 ha. To collect more comprehensive data, the space between plots was 50 m. The circular plot was divided into three compartments (Figure 3), namely compartment “a” with a radius (r) of 2 m (calculating the seedling stage with the characteristics of a total height (h) of 30 cm $\leq$ h $\leq$ 1.30 m), compartment “b” with a radius of 5 m (measuring trees (sapling stage) that had a diameter at breast height (DBH, 1.3 m height) 1 cm $\leq$ DBH <10 cm, and compartment “c” with a radius of 17.8 m (measuring trees with a DBH $\geq$ 10 cm).

Measured vegetation parameters were species and family names, diameter at height breast (DBH; 1.3 m) and total height, whereas analysed soil parameters were physical, biological and chemical properties. The soil parameters were analysed in the soil and vegetation laboratory Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP), Bogor Regency, West Java Province, Indonesia, which has implemented national standards of SNI 19-17025-2000 and ISO 17025 since 2007. The vegetation and soil inventory analysis is shown in Table 1.

Reclamation process in Indonesia

The reclamation process in Indonesia mostly is as follows:

a. Overburden management: Overburden placement can be conducted in-pit dump or backfilling and outside the pit (out-pit dump). Backfilling the ex-pit aims to reduce the number of mine holes (void). Overburden with PAF material must be managed by the encapsulation method, where Potential Acid Forming (PAF) content is encapsulated and covered by Non-Acid Forming (NAF) material as acid water forming prevention.
b. Soil spreading: Soil can be obtained from the topsoil bank or direct spreading from land clearing. Soil thickness for re-vegetation purposes is generally more than 30 cm.

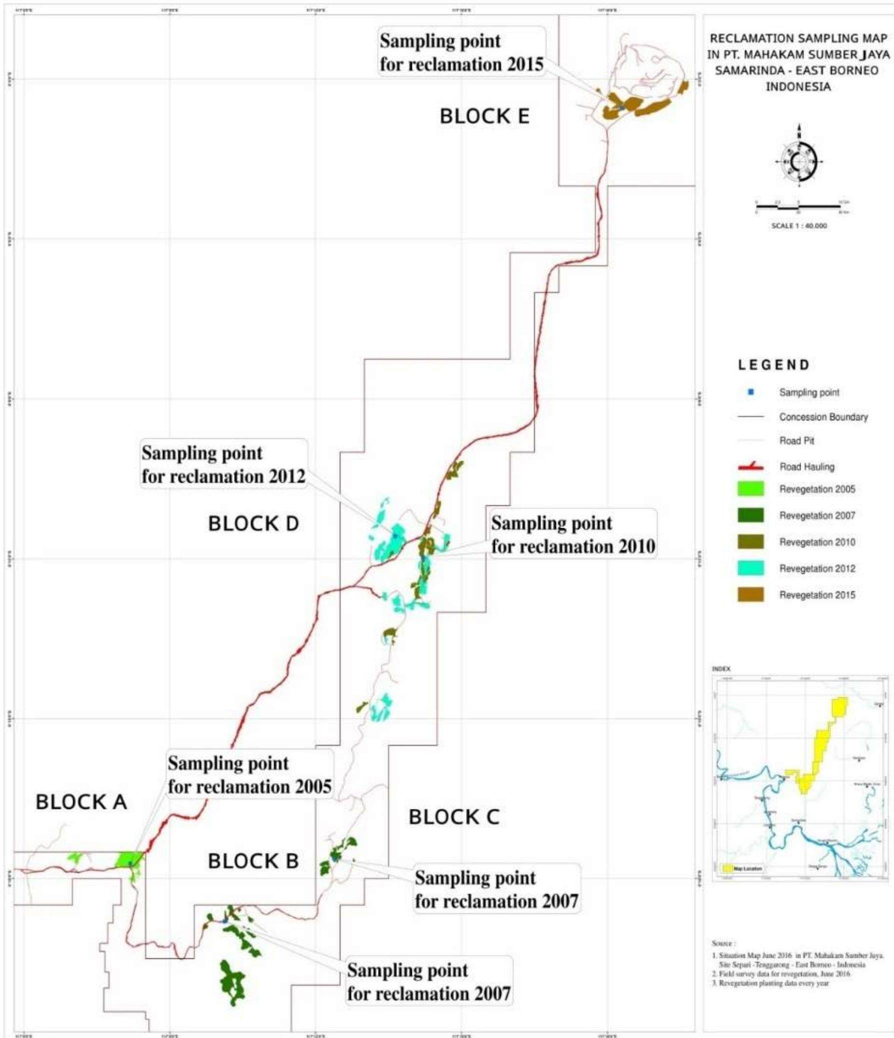


Figure 1. Sampling points of the vegetation inventory (image source: Yunanto, 2018).

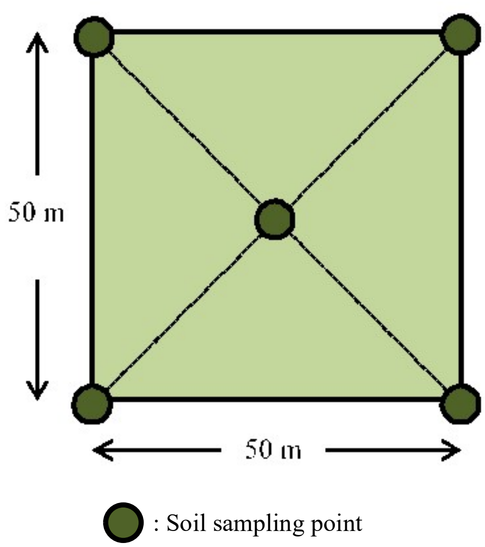
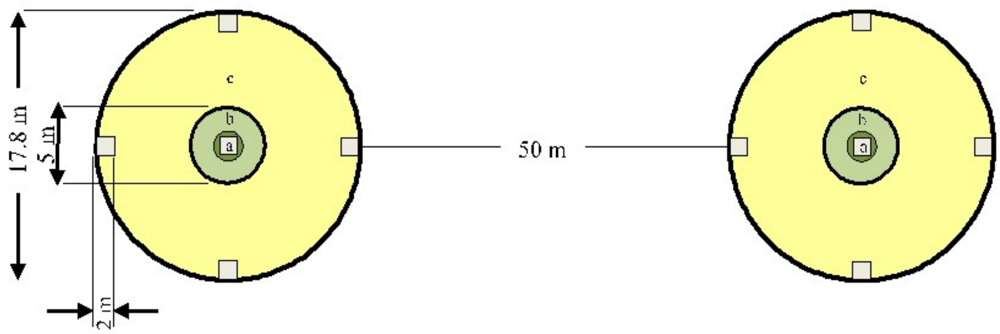


Figure 2. The layout of soil sampling.



▢ = soil cover and canopy cover

- a; calculating the seedling stage (total height (h) of 30 cm ≤ h ≤ 1.3 m)
- b; measuring the sapling stage (DBH = 1.3 m h) 1 cm ≤ DBH < 10 cm
- c; measuring the tree stage (diameter at breast height; DBH = 1.3 m h) ≥ 10 cm

Figure 3. Sampling design in a vegetation inventory.

Table 1. Data analysis of vegetation inventory and soil sampling.

Analysis	**Source**
Shannon Wiener Index (H\`): $H' = -\sum \mathrm{pi} \ln \mathrm{pi}$ where; pi = the proportional abundance of the i^{th} species (ni/N)	Magurran, 1988
Arithmetic mean diameter ($\bar{d}$): $\bar{d} = \frac{\sum_{i=1}^{N} di}{N}$ where: di: diameter of the individual tree N: total number of trees of the stand	Brodbeck, 2004
Total stand basal area (G): $G = \sum_{i=1}^{N} gi$; and $gi = \frac{\pi}{4} . di^2$ where: gi: basal area of the i^{th} trees di: dbh of the trees	Lu, 1999
Arithmetic mean height($h_{\bar{d}}$): $h_{\bar{d}} = \frac{\sum_{i=1}^{N} hi}{N}$ where: hi: height of the individual tree n: total number of trees of the stand	
Soil Cover ($\overline{SC}$) $= \sum_{i=1}^{N} \dot{\overline{SC}}_i$; and $\overline{SCi} = \sum_{i=1}^{n} \frac{number\ of\ screened\ soil\ cover}{256}$ where: SCi: number of screened soil cover in the sub plot N: number of plot n: number of sub plot	
Canopy Cover (T): T = $100 - T_i$ $T_i = \left(T_1 + T_2 + T_3 + .. + \frac{T_n}{N}\right) \times 1.04$ where: Ti: Canopy opening Tn: Scale of canopy opening on each sampling point N: Number of sampling points	Supriyanto and Irawan, 2001
Standard deviation/SD (σ_x): $\sigma_x = \pm\sqrt{\sigma_x{}^2}$ and variance (σ_x^2): $\sigma_x{}^2 = \frac{\sum_{i=1}^{N} (Xi - \mu)^2}{N}$	
Physical analyses: Conductivity and Bulk density	SEAMEO BIOTROP
Chemical analyses: pH: H_2O and $CaCl_2$, Organic Carbon (OC), N-total, P_2O_5 availability, Cation Exchange Capacity	SEAMEO BIOTROP
Biological analyses: Isolation of mycorrhiza	SEAMEO BIOTROP

c. Land stabilization and erosion control: Erosion, sedimentation and slides are common problems in the reclamation area. Meanwhile, some prevention infrastructures such as terraces, dams, sediment ponds and cover crops such as *Centrosemapubescens, Calopoginium mucunoides, Calopogonium caeruleum, Psopocarphus polustris, Desmodium ovalifolium, Mucuna conchinchinensis, Pueraria javanica* and *Pueraria phascoloides* are used to control.
d. Re-vegetation: To restore ex-mining areas, the composition of local and pioneer trees is ruled. The local trees are more than 40%, while the pioneer trees are less than 60% per hectare.
e. Maintenance: Replanted, fertilization and growth protection are maintenance programs to meet 100% success.

Evaluation based on MEMR Decree No. 1827.K/30/MEM/2018

The MEMR guidelines for the assessment of reclamation are based on the area completion and reclamation quality. The guidelines are as follows:

a. Land-contouring (60%): surface management and backfilling (40%), soil spreading (10%), and erosion control and water management (10%).
b. Re-vegetation (20%): cover crop growth (2.5%), fast growing growth (7.5%), local tree growth (5%) and acid mine drainage (AMD) control (5%).
c. Final completion (20%): canopy cover (10%) and maintenance (10%).

Evaluation based on MF Regulation No. P.60/Menhut-II/2009

Mine reclamation success evaluation based on the MF Regulation No. P.60/Menhut-II/2009 is only for the ex-mining area located in the forestry area. In general, this regulation consists of land contouring, erosion and sedimentation control and re-vegetation as follows:

a. Land-contouring (30%): surface management (backfilling of ex-mining land, area, stability and soil spreading).
b. Erosion and soil sediment control (20%): soil conservation facility, cover crop planting and erosion and sedimentation.
c. Re-vegetation (50%): completion area, plant growth, local trees composition and tree healthy.

In this study, the evaluation of both success criteria was focused on soil and re-vegetation. Some parameters are assessed in the criteria such as soil property (pH), soil cover by cover crop plantation, plant growth, density, local trees composition and canopy cover. In particular, pH is the only property that is evaluated in MEMR criteria. Moreover, the study put some soil properties as a considerable recommendation in future policy, such as electrical conductivity, bulk density, organic carbon, total nitrogen, phosphate, Cation Exchange Capacity (CEC) and the number of mycorrhiza spores. The plant growth is mentioned in both policies and indicates the main success of the re-vegetation process. The density and species composition are evaluated based on MF criteria, while canopy cover is essential in the MEMR criteria as completion. To assess the re-vegetation criteria, some parameters were used in the study such as mean total height and DBH to evaluate the growth, density in all stages to evaluate the plant density, species and family number to assess the composition, as well as basal area and densiometer measurement to evaluate the canopy cover.

Results and Discussion

Soil condition

As a growth media, the soil is crucially important to indicate reclamation success. The soil used for mine reclamation is a mixture of topsoil with subsoil. Mining companies generally spread the soil, ranging from 30-50 cm in the reclamation area. The soil property that is mentioned in both regulations is the only pH in MEMR criteria. pH is also the basic chemical property to be tested. The measurement resulted from a 1-yr-old plantation that had lower pH than SNF (Table 2). The 1-yr-old plantation had a very low pH value of 3.23-3.27, while the 11-yr-old plantation had a fairly high pH within 5.67-6.35.

Nevertheless, it fluctuated in other stand types indicating the different locations had a variation of pH value. The results showed that pH required consideration as a success criterion. Older reclamation age could not create proper pH (in good and medium categories) in certain locations. However, soil pH has a strong relationship with geochemical properties in the overburdened material, particularly PAF content (Dutta et al., 2017). PAF material forms AMD when it contacts the air and water. In general, the soil in all reclamation areas (except the 11-yr-old plantation) had a higher bulk density (high clay content) within the range of 1.81-2.00 g/cm^3 than SNF. High bulk density inhibits root elongation rates and overall plant growth. Soil texture in the reclamation area was highly dependent on the soil material (subsoil or overburden) used at the beginning of the reclamation process. High clay content in the soil could have derived from mudstone (clay) in the overburden. In addition, lower amounts of organic matter (Sofyan et al., 2017), soil compaction by the excavator and grazing may cause the high bulk density in the reclamation areas (Yunanto, 2018). Similar to pH, the rest of the parameters were fluctuated in different stand types and described no relations to the reclamation ages. Due to the geological condition that may influence the soil properties, soil treatment and species selection are required to manage reclamation success (Amanah and Yunanto, 2019). Spores were found in all reclamation areas. It demonstrated that the infertile soil conditions of the ex-mining area were still able to provide a suitable environment for the life of mycorrhiza.

Table 2. Candidate parameters for success criteria of mine reclamation from soil condition.

Parameter	Unit	1-yr-old plantation	4-yr-old plantation	6-yr-old plantation	9-yr-old plantation	11-yr-old plantation	SNF	Note	Conclusion
Electrical conductivity	µS/cm ± SD	343.07 ± 469.58	304.62 ± 212.09	123.18 ± 116.87	145.68 ± 85.37	252.16 ± 75.18	277.26 ± 117.30	6-yr-old plantation ± 44% of SNF	*
Bulk density	g/cc ± SD	1.83 ± 0.19	2.00 ± 0.15	1.98 ± 0.33	1.83 ± 0.32	1.81 ± 0.15	1.64 ± 0.16	higher than SNF	**
pH (H_2O)	± SD	3.27 ± 0.44	5.36 ± 1.30	5.17 ± 0.40	4.48 ± 0.75	6.35 ± 0.88	5.08 ± 0.48	1-yr-old plantation ± 64% of SNF	*
pH ($CaCl_2$)	± SD	3.23 ± 0.40	4.64 ± 1.49	4.49 ± 0.63	3.93 ± 0.80	5.67 ± 1.09	4.58 ± 0.26	1-yr-old plantation ± 71% of SNF	*
Organic C	% ± SD	0.82 ± 0.17	1.38 ± 0.64	0.39 ± 0.31	1.49 ± 0.65	0.39 ± 0.17	1.14 ± 0.36	6 and 11-yr-old plantation ± 34% of SNF	*
Total N	% ± SD	0.15 ± 0.05	0.22 ± 0.04	0.12 ± 0.05	0.25 ± 0.05	0.12 ± 0.03	0.26 ± 0.06	6 and 11-yr-old plantation ± 46% of SNF	*
P_2O_5	ppm ± SD	5.02 ± 1.71	26.32 ± 31.16	20.90 ± 27.23	6.56 ± 2.62	136.70 ± 100.46	9.66 ± 3.92	1-yr-old plantation ± 52% of SNF	*
CEC	cmol/kg ± SD	14.69 ± 4.76	17.65 ± 1.96	10.19 ± 5.90	17.73 ± 3.72	19.77 ± 2.15	12.65 ± 3.49	6-yr-old plantation ±81% of SNF	*
Mycorrhiza	N spore/50 g soil	242	1,283	5,423	1,728	843	530	1-yr-old plantation ±46% of SNF	*

Note: *need consideration; **not a candidate of success criteria.

Mycorrhiza can be used as an alternative to improve and develop the role of various other species of the tree during the re-vegetation effort (Suharno and Sancayaningsih, 2013).

Vegetation structure

The results showed that the reclamation area generally had a higher mean value of stand structure than the SNF (Table 3), namely soil cover, mean total height, DBH, the density of trees stage, basal area and canopy cover. Cover crop aims to minimize soil erosion, particularly in the early stage of reclamation. Although the soil cover generally has a small value, but mostly in all reclamation areas, the value was higher than SNF. Uneven distribution of seeds or erosion may cause low growth of the cover crop in the reclamation areas.

The mean total height of a 9-yr-old plantation (15.87 m) was higher than SNF (13.99 m) and made it considered a success criterion. The success can be complied between 6 and 9-yr-old plantation. This condition was occurred because the dominant tress was *Paraserianthes falcataria*. The *P. falcataria* can reach heights of even 45 m (Kurinobu et al., 2007). DBH in a 4-yr-old plantation (28.42 cm) was exceeded SNF (21.40 cm). It was possibly achieved between 1 and 4-yr-old plantation. In general, the species in the 4-yr-old plantation were the fast-growing species *Enterolobium cyclocarpum* (204/ha) of the Fabaceae family. This species grows 20 to 30 m in height and has a trunk diameter of up to 3 m (Barrientos-Ramirez et al., 2015). The results showed the plant growth was proper as criteria where the total mean height and DBH were recommended as the parameters. Moreover, the standard of growth ratio in MEMR guidelines was biased due to the limitation of the method and scoring system.

One parameter of MF re-vegetation criteria is trees density, where a minimum of 625 trees per ha (with 4 x 4 plant spacing). The study included measurement of density in all stages. The result showed the density of trees stages went beyond the SNF in the 6-yr-old plantation. It indicated that the density met the criteria between 4 and 6-yr-old plantation. Moreover, compared to the MF regulation, even the highest density in a 9-yr-old plantation was failed to meet an impeccable score. However, score re-assessment is necessary to adjust the possibility of achievement in comparison with present SNF recently. In contrast, the density of saplings and seedlings stage was unavailable to meet the SNF. The highest density of saplings occurred in 9-yr-old plantation (55%) and the density of seedlings in 11-yr-old plantation (16%). It may indicate the natural regeneration was still ongoing, and the use of seedlings and saplings density measurement was inadvisable.

The canopy cover as completion in MEMR criteria is the hardest to meet (Amanah and Yunanto, 2019). MEMR attempts to improve the assessment method by using the aerial photo to adjust the cover. Otherwise, in this study, basal area measurement and canopy cover using a densiometer were analysed to evaluate the canopy cover criteria. Comparing to the basal area and canopy cover of SNF, the 4-yr-old plantation had a higher basal area of 19.35 m^2/ha and canopy cover of 85% (the standard > above 80%). In general, the canopy cover was possible to meet between 4-yr and 11-yr-old plantation. The basal area calculation and canopy cover measurement using the densiometer are recommended in the improved assessment method.

Species composition

In general, the youngest (1 and 4-yr-old) plantations had the lowest numbers of species and families among the reclamation areas for all growth stages (seedling, sapling and tree). This occurred because of the high mortality rate and the limited amount of natural regeneration in the 1-yr-old plantation (open area, directly exposed to sunlight) and in the 4-yr-old plantation (grazing (buffalo) by surrounding communities) (Yunanto, 2018).

The number of species and families of SNF was the highest compared to all reclamation ages for all growth stages (seedling, sapling and tree). The 9-yr-old plantation had the highest number of species and families for tree and sapling stages among the reclamation areas (Table 4). For the seedling stage, the 11-yr-old plantation had the highest number of species among all reclamation ages. As well as for the diversity index of Shannon Wiener (H'), SNF had the highest value compared to all stand types and growth stages (seedling, sapling and tree). The 9-yr-old plantation had the highest H' for the tree stage among the reclamation areas, namely H’ = 1.52. Meanwhile, the 6-yr-old plantation had the highest H' of sapling stage, i.e. H’ = 2.17, and the 11-yr-old plantation had the highest mean values of diversity index for the seedling stage, i.e. H' = 1.82.

The low species number of natural regeneration in the reclamation area causes the low value of H’. This condition is probably caused by infertile soil conditions, low topsoil thickness (30-50 cm), compacted soil or high clay content. In general, mining companies use thin topsoil (30-50 cm) for re-vegetation. Moffat (1995) stated that 'rootable' soil profiles with a minimum thick of 1.0 m must be sufficient to obtain rooting of tree species suitable for various soil types and climate, including in mine reclamation areas. However, based on the data, the species composition is required to be re-evaluated as one parameter. Since the soil becomes the key and possibly has a wide distribution of uncontrolled properties, species selection is a strategy. In a particular condition with high acidic and unexpected fertility, there are limited species options to be planted. Therefore, the species composition becomes a tight parameter to meet (Amanah and Yunanto, 2019).

Table 3. Candidate parameters for success criteria of mine reclamation from vegetation structure.

Parameter	**Unit**	**1-yr-old plantation**	**4-yr-old plantation**	**6-yr-old plantation**	**9-yr-old plantation**	**11-yr-old plantation**	**SNF**	**Note**	**Conclusion**
Soil cover	% ± SD	21.99 ± 20.01	55.95 ± 35.72	53.45 ± 25.11	70.88 ± 10.57	76.61 ± 14.09	28.06 ± 17.27	between 1 and 4-yr-old plantation	**
Mean total height (trees)	m ± SD	4.11 ± 1.81 (saplings stage)	11.41 ± 2.11	12.77 ± 1.99	15.87 ± 4.98	16.85 ± 3.32	13.99 ± 3.99	between 6 and 9-yr-old plantation	*
mean DBH (trees)	cm ± SD	3.49 ± 1.95 (saplings stage)	28.42 ± 2.83	26.42 ± 3.17	27.74 ± 5.03	27.05 ± 2.72	21.40 ± 2.43	between 1 and 4-yr-old plantation	*
Mean density (trees)	N/ha ± SD	2	272 ± 70	394 ± 121	469 ± 116	347 ± 102	332 ± 78	between 4 and 6-yr-old plantation	*
Mean density (saplings)	N/ha ± SD	382 ± 288	25 ± 0	293 ± 20	1,629 ± 305	1,616 ± 259	2,978 ± 128	9-yr-old plantation 55% of SNF	**
Mean density (seedlings)	N/ha ± SD	955 ± 413	0.00	716 ± 142	282 ± 59	2,625 ± 260	16,307 ± 829	11-yr-old plantation 16% of SNF	**
Mean basal area (trees)	m^2/ha ± SD	0.02 ± 0.02 (saplings stage)	19.35 ± 4.69	25.66 ± 9.73	35.04 ± 11.11	23.29 ± 7.23	14.45 ± 4.41	between 1 and 4-yr-old plantation	*
Canopy cover	% ± SD	18.38 ± 16.87	84.83 ± 17.27	99.33 ± 1.35	98.33 ± 2.45	96.17 ± 6.30	100.00 ± 0.00	between 1 and 4-yr-old plantation	**

Note: *candidate of success criteria; **needs consideration.

Table 4. Candidate parameters for success criteria of mine reclamation from species composition.

Parameter	**1-yr-old plantation**	**4-yr-old plantation**	**6-yr-old plantation**	**9-yr-old plantation**	**11-yr-old plantation**	**SNF**	**Note**	**Conclusion**
Species number (trees)	1 (planted)	4 (3 planted, 1 naturally grow)	6 (3 planted, 3 naturally grow)	14 (5 planted, 9 naturally grow)	10 (4 planted, 6 naturally grow)	67	9-yr-old plantation ± 21% of SNF	needs consideration
Species number (saplings)	4 (3 planted, 1 naturally grow)	2 (2 planted)	11 (4 planted, 7 naturally grow)	13 (1 planted, 12 naturally grow)	12 (1 planted, 11 naturally grow)	50	9-yr-old plantation ± 26% of SNF	needs consideration
Species number (seedlings)	3 (3 naturally grow)	0	5 (5 naturally grow)	3 (3 naturally grow)	8 (8 naturally grow)	34	11-yr-old plantation ± 24% of SNF	needs consideration
Family number (trees)	1 (planted of species number)	2 (3 planted and 1 naturally grow of species number)	3 (3 planted and 3 naturally grow of species number)	11 (5 planted and 9 naturally grow of species number)	5 (4 planted and 6 naturally grow of species number)	31 of 67 species number	9-yr-old plantation ± 36% of SNF	needs consideration
Family number (saplings)	3 (3 planted and 1 naturally grow of species number)	1 (2 planted of species number)	7 (4 planted and 7 naturally grow of species number)	10 (1 planted and 12 naturally grow of species number)	9 (1 planted and 11 naturally grow of species number)	24 of 50 species number	9-yr-old plantation ± 42% of SNF	needs consideration
Family number (seedlings)	3 (3 naturally grow of species number)	0	5 (5 naturally grow of species number)	3 (3 naturally grow of species number)	6 (8 naturally grow of species number)	21 of 34 species number	11-yr-old plantation ± 29% of SNF	needs consideration
H’ (trees)	0.00	0.77	1.15	1.52	1.16	3.48	9-yr-old plantation ± 44% of SNF	needs consideration
H’ (saplings)	1.35	0.69	2.17	1.27	1.32	2.95	6-yr-old plantation ± 74% of SNF	needs consideration
H’ (seedlings)	0.57	0.00	1.30	0.42	1.82	2.75	11-yr-old plantation ± 66% of SNF	needs consideration

Based on this study, some parameters can be recommended, such as mean total height, mean DBH, mean density for trees, and mean basal area in future policy making. Soil parameters such as electrical conductivity, pH, organic carbon, total nitrogen, phosphate, CEC and mycorrhiza soil cover, mean density for saplings and seedlings, canopy cover and species composition require consideration when incorporated into policy. As for bulk density is inadvisable to be the standard in the policy. Further research is needed to determine the average based on SNF conditions in Indonesia.

Conclusion

Mine reclamation in forestry areas requires more strategies to comply criteria of MF and MEMR regulations. Some parameters and assessment methods need to re-evaluate to create a more credible site evaluation. In terms of soil criteria, some chemical and biology parameters are advisable to consider further SNF conditions in Indonesia. Success criteria for vegetation structure are easier to meet than species composition.

Acknowledgements

We would like to thank Erasmus Mundus for funding this research and PT Mahakam Sumber Jaya for their support during this research.

References

Amanah, F. and Yunanto, T. 2019. Mine reclamation period to successfully meet criteria in Indonesia. *Proceedings of the 13th International Conference on Mine Closure*. 3-5 September 2019. Perth, Australia. p. 1303-1314.

Barrientos-Ramírez, L., Vargas-Radillo, J.J., Segura-Nieto, M., Manriquez-Gonzalez, R. and Toral, F.A. 2015. Nutritional evaluation of mature seeds of *Enterolobium cyclocarpum* (parota) from diverse ecological zones in western Mexico. *BOSQUE* 36: 95-103, doi:10.4067/s0717-92002015000100010.

Brodbeck, F. 2004. *Structure and Processes in Traditional Forest Gardens of Central Sulawesi, Indonesia.* Cuvillier Verlag Göttingen. Göttingen, Germany. 212p.

Doupé, R.G. and Lymbery, A.J. 2005. Environmental risks associated with beneficial end uses of mine lakes in Southwestern Australia. *Mine Water and the Environment* 24:134-138, doi:10.1007/s10230-005-0084-0.

Dutta, M., Saikia, J., Taffarel, S.R., Waanders, F.B., de Medeiros, D., Cutruneo, C.M.N.L., Silva, L.F.O. and Saikia, B.K. 2017. Environmental assessment and nano-mineralogical characterization of coal, overburden and sediment from Indian coal mining acid drainage. *Geoscience Frontiers* 8(6):1285-1297, doi:10.1016/j.gsf.2016.11.014.

James, F.C. and Shugart, H.H. 1970. A quantitive method of habitat description. *~~National~~ Audubon ~~Society~~: Field Notes* 24(6): 727-736.

Kurinobu, S., Prehatin, D., Mohammad, N., Matsune, K. and Chigira, O. 2007. A provisional growth model with a size–density relationship for a plantation of *Paraserianthes falcataria* derived from measurements taken over 2 years in Pare, Indonesia. *Journal of Forest Research* 12(3):230-236, doi:10.1007/s10310-007-0007-y.

Lamprecht, H. 1989. *Silviculture in the Tropics.* Deutsche Gesellschaft für Technische Zusammenarbeit. Eschborn, Rossdorf, Germany. 296p.

Lloyd, M.V., Doherty, M.D., Jeffree, R.A., John, J., Majer, J.D., Osborne, J.M. and Nichols, O.G. 2002. *Managing the Impacts of the Australian Minerals Industry on Biodiversity.* Australian Centre for Mining Environmental. London, UK. 120p.

Lu, Y. 1999. *Development of Models for Sustainable Management of the Mixed Tropical Rain.* Dissertation University of Göttingen. Verlag Enrich Goltze GmbH & Co. KG. Göttingen, Germany.

Magurran, A.A. 1988. *Ecological Diversity and Its Measurement.* Springer. Dordrecht, The Netherlands. 179p.

Martin, J. and Gower, T. 1996. Forest succession. *Forestry Facts*: 78-81.

Moffat, A.J. 1995. Minimum soil depths for the establishment of woodland on disturbed ground. *Arboricultural Journal* 19: 19-27.

Slingenberg, A., Braat, L., Windt, H., Rademaekers, K., Eichler, L. and Turner, K. 2009. *Study on Understanding the Causes of Biodiversity Loss and the Policy Assessment Framework.* ECORYS Nederland BV. Rotterdam, The Netherlands.

Sofyan, R.H., Wahjunie, E.D. and Hidayat, Y. 2017. Physical characterization and soil moisture at different reclamation's age of mined land. *Buletin Tanah dan Lahan* 1(1):72-78 (*in Indonesian*).

Subowo, G. 2011. Environment friendly open pit mining systems and reclamation post-mining efforts to improve the quality of land resources and soil biodiversity. *Jurnal Sumber Daya Lahan* 5 (2): 83-94 (*in Indonesian*)..

Suharno and Sancayaningsih, R. P. 2013. Arbuscular Mycorrhizae Fungi: The potential use of heavy metal mycorrhiza-remediation technology in mined field rehabilitation. *Bioteknologi* 10(1):23-34, doi:10.13057/biotek/c100104 (*in Indonesian*).

Supriyanto and Irawan, U.S. 2001. *Technique for Measuring Canopy Cover and Canopy Opening Using a Spherical Densiometer*. Laboratorium Silvikultur SEAMEO-BIOTROP. Bogor, Indonesia (*in Indonesian*)

Yunanto, T. 2018. *Site and Vegetation Development After Coal Mine Reclamation in Kalimantan, Indonesia.* Cuvillier Verlag. Göttingen, Germany. 272p.