EVALUATION OF REVEGETATION PRACTICES IN POST-MINED AREAS OF INDONESIA

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Received 16 March 2018 / Accepted 11 July 2019

ABSTRACT

In compliance with government regulations, mining companies in Indonesia are obliged to reclaim and return a post-mined area into its pre-mining condition. Revegetation, as part of reclamation activity, performs a significant role in the rehabilitation of degraded post-mined areas to restore their productive land uses. Hence, this study aimed to assess tree growth on the reclamation sites across four mining companies in East Kalimantan, South Sulawesi, South Sumatra, and West Java in Indonesia and to evaluate whether the companies have met the legal requirements set for site revegetation. The success parameters were based on the applicable regulations of the Ministry of Environment and Forestry (MOEF) P.60/Menhut-II/2009 and tree growth parameters (stem diameter, total height and basal area). The parameters set by MOEF included revegetation realization, survival rate, tree density, tree health, species composition and rotation length. The four mining companies applied the two-phase planting method that included the planting of *Enterolobium cyclocarpum* for the first phase; and in the second phase, the slow growing native species, such as *Intsia palembanica*, *Syzygium polyanthum*, *Shorea* spp. and *Elmerrillia tsiampaca*. The tree growth parameters showed different performances over species and reclaimed sites. An extremely high growth of stem basal area of 57.6 m^2/ha in 11 years, was recorded in the *E. cyclocarpum* stand of the Mining Company in South Sulawesi. All four mining companies strived to comply with the regulation with scores of revegetation success ranging from 15 to 25 out of 25 possible points. However, these favorable results may not be representative of all the mining companies, as the ones assessed were only those voluntarily supporting this research. Moreover, each of the four companies made some distinct efforts in implementing post-mining revegetation, such as by establishing plots of *Melaleuca cajuputi* trees producing cajuput oil and polycultures of native species.

Keywords: mining, reclamation, reforestation, rehabilitation, success parameters

INTRODUCTION

The increasing demands for raw materials in modern society have expanded the extraction of mining commodities into even more natural areas in remote regions. These regions are often those identified as priorities for biodiversity conservation and nature preservation (ICMM (2010). The mining sector in Indonesia undoubtedly plays a pivotal role in the country's economic development, contributing approximately 9% to Indonesian Gross Domestic Product (PwC 2015). Mining commodities in Indonesia are classified into three categories: minerals, coal, and oil & gas. The mineral and coal reserves are distributed throughout the country spanning from Sumatra to the Papua Islands. In contrast to its contribution to economic development, the extraction and processing of mining reserves can cause environmental problems. These include extensive land disturbance, loss of forest cover and habitat, disruption of flora and fauna, changes in microclimate, surface and ground water contamination, emissions, dust, and noise (McMahon *et al.* 2000; Greb *et al.* 2006). Considering these possible impacts, the mining companies operating in Indonesia are legally

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obliged to implement good mining practices and to ensure reclamation and revegetation on their post-mined sites. The aim of reclaiming the post-mined sites is to recover the degraded land and vegetation and to restore its original land use function.

Principally, the management of mining extraction is under the power of the state, i.e., the Government of Indonesia (GOI). The main regulatory authority responsible for the mining business is the Ministry of Energy and Mineral Resources (MOEMR). The Ministry of Environment and Forestry (MOEF) is responsible for environmental and forestry issues when mining is conducted inside state forest areas covering 64% of the terrestrial surface of the country (Ditjen PKTL 2017). Mining activity is allowed in production and protection forest, but not in conservation forest. The MOEF is accountable for issuing the 'forest lending use permit' (*Izin Pinjam Pakai Kawasan Hutan*–IPPKH), a permit to utilize state forestland for development activities outside the forestry sector based on leasehold mechanisms.

Forestry science has taken a substantial role in determining how to reclaim post-mined areas in Indonesia, particularly reforestation practices. These include the selection of tree species, plant propagation, planting technique, plantation maintenance and monitoring of success indicators of the revegetation practices (Mansur 2013). Reclamation of post-mining concessions located in state forestland has to follow the regulations stipulated by the MOEF. Regardless of the land use, the reclamation activity is also assessed by the MOEMR for the release of reclamation bonds. These are allocated funds provided by mining concession holders as a guarantee to carry out post-mining reclamation. Consequently, the mining companies in Indonesia have to fulfil their responsibilities to comply with government regulations. The current study aimed to evaluate how the four Indonesian mining companies, which voluntarily participated in the study, implemented their revegetation protocol as a component of the legally required reclamation program.

MATERIALS AND METHODS

Study Area

The study was carried out in four mining companies that supported the research, including a Coal Mining Company in South Sumatra (CMCSS), a Gold Mining Company in West Java (GMCWJ), a Coal Mining Company in East Kalimantan (CMCEK), and a Nickel Mining Company in South Sulawesi (NMCSS) (Fig. 1). The selection is purposive and positive in the sense that other companies that were notified did not positively respond to the request to take part in the study. The concession areas are located inside state forestlands, except the concession of the Gold Mining Company–West Java, which is located inside a non-state forestland.

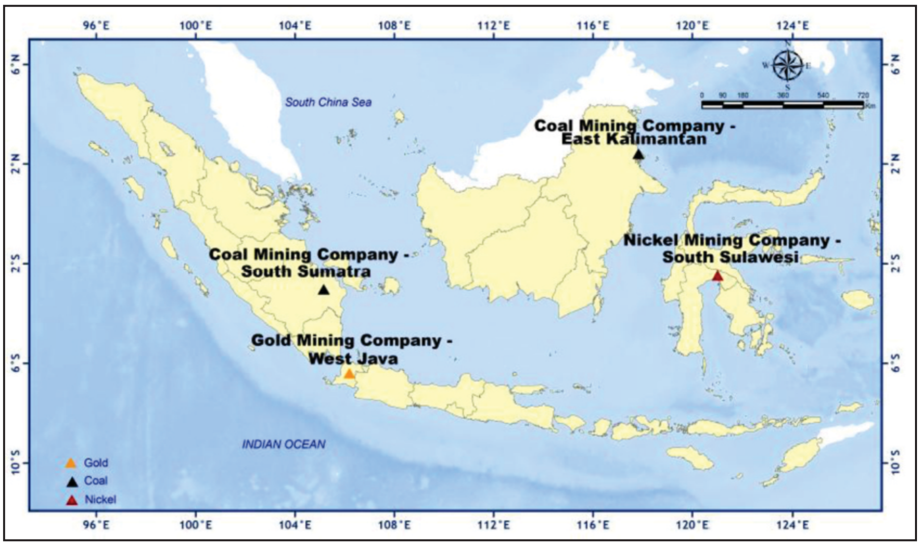

Figure 1 Location map of the mining companies' and their commodities

Sampling Procedure and Sample Size

Referring to the MOEF regulation for evaluating the reclamation activities in state forestlands (*Peraturan Menteri Kehutanan No. P.60/Menhut-II/2009*), this study used systematic sampling with a random start. The sampling intensity employed included 5% of the revegetated areas, and the size of the sampled plots were 40 x 25 m (0.1 ha). Since the size of these areas varied in each company and the areas were scattered throughout the concession, this study stratified the compartments of the revegetation area based on the planting years. Accordingly, the sampling area and number of sampling plots were obtained by multiplying the sampling intensity (5%) and the size of the compartment in each planting year. The distance between each plot was around 50 to 100 m, depending on the condition of the revegetation area. The sampling plots were then established based on the reviews of maps and an ArcGIS database, as well as a reconnaissance survey. A total area of 7.8 ha of sampling plots were established.

Information and Data Collection

Research information and data were collected from primary and secondary sources. Secondary data were gathered mainly from companies' data on their reclamation and revegetation programs. The primary data were collected through observation and forest inventory that involved measurement of parameters for evaluating revegetation success. The main reference used for assessment was the MOEF Regulation P.60/Menhut-II/2009 on the Assessment Guideline of Forest Reclamation Success. Based on this regulation, the parameters observed and recorded, were the living trees (survival rate), tree density (number of trees/ha), tree health and species composition based on rotation length groups (short rotation and long rotation species). The tree health status was visually observed based on vigor assessed by leaf color, stem form, crown form, and symptoms of diseases. Growth parameters measured included stem diameter at breast height (DBH) and total tree height. The DBH was taken at 1.3 m from the ground using a diameter tape. Planted trees that were below this height were recorded and counted as living trees. For the purpose of assessment using the GOI regulation, the planted trees with bifurcation (two stems) or more were counted as a single tree. However, all the stems were individually measured for basal area determination. The total height of trees between 1 and 7 m was measured using a calibrated stick, while for trees above 7 m, a Haga hypsometer was used for height measurement.

Data Analyses

The success parameters determined by GOI regulations included: (i) revegetation area planted (actual) compared to target area (planned) (%); (ii) survival rate (%); (iii) tree density (number of trees/ha); (iv) species composition (%); and (v) tree health (%).

i. The actual revegetation area was compared to the planned revegetation area (in hectares), based on a report review of the company's reclamation activity submitted and approved by the GOI.
ii. Survival rate was analyzed by comparing the number of living trees in a plot with the initial number of planted trees.
iii. Tree density was analyzed by dividing the total number of living trees in a plot by the plot area. This was then compared to the minimum required density of 625 trees/ha.
iv. For species composition, the number of trees considered as long rotation species was divided by the total number of living trees in the plot. The GOI regulation requires the post-mined areas to be revegetated using locally known species, either native or exotic, which are categorized as long rotation species. The preferred planted trees are those generating high economic value products, such as timber, resin and fruits. Indonesia does not have a national classification for rotation length categories. Therefore, to analyze this parameter, a rotation length category for forest plantation developed by the Food and Agriculture Organization of the United Nations (FAO 2001) was used as a reference. For the assessment criteria of long rotation species, this study used the threshold of medium and long rotation length categories, which was $\geq$ 20 years.
v. Tree health was analyzed by comparing the healthy trees with the total number of living trees in a plot.

Table 1 Sampling sites and number of sampling plots in the study areas

Concession areas	Stand age (years)	Total revegetation area (ha)[a]	Compartment size (ha)	Sampling plot (ha)	% Sampling plot from total revegetation area
Coal Mining Company South Sumatra (CMCSS)	1	26.2	5	0.3	1.1
	2	17.1	2.2	0.2	1.2
	3	19.3	1.6	0.2	1.0
	6	48.9	7.1	0.4	0.8
	7	42.4	4.6	0.3	0.7
Gold Mining Company West Jaya (GMCWJ)	1	1.5[b]	0.9	0.9	60
	2	0.4[b]	0.2	0.2	62.2
	3	0.8[b]	0.2	0.2	25
	5	1.5[b]	0.3	0.3	20
	6	8.0[b]	0.2	0.2	2.5
Coal Mining Company East Kalimantan (CMCEK)	2A		2.7	0.2	
	2B	68.0	6	0.4	1.2
	2C		3.1	0.2	
	4A		4.1	0.3	
	4B	76.2	2.2	0.2	1.2
	4C		7.2	0.4	
	6	81.4	9.6	0.5	0.6
Nickel Mining Company South Sulawesi (NMCSS)	1	74.1	6	0.3	0.4
	2	78.1	9	0.5	0.6
	4	90.0	7.6	0.4	0.4
	6A	114.9	2.6	0.2	0.3
	6B		3	0.2	
	11A	512.9	4	0.2	0.1
	11B		8.3	0.4	
	13	132.0	4	0.2	0.2
Total Sampling Plots				7.8	

Notes: [a] The total revegetation area for both state forestland and non-state forestland; [b] Estimates of revegetation area planted with trees. Some of the reclaimed sites were planted with herbaceous legume cover crops (LCC). A, B and C describe different stands of the same year.

The next step was to score the parameters as determined by the regulation (Table 2). Based on an equal score weight of each of the five parameters and five scores per parameter, the maximum score was 25. The growth parameters included the mean values of DBH, total height and stem basal area. The stem basal area was determined using the formula $g = \pi/40000 \times d^2$, where g is the stem basal area in m^2, π is 3.1415, and d is the average DBH in cm. The stand basal area G in m^2/ha was determined by dividing the total g mean values in m^2 of a plot by the plot size in hectares.

RESULTS AND DISCUSSION

Revegetation Establishment

The mining companies used the two-phase planting method. The first planting phase included the light demanding and pioneer species, which were mostly fast growing, to provide shade to the species of the second planting phase. After 2-3 years, or when the crowns of pioneer species provided enough shading, the second planting was implemented. This second phase, called enrichment planting, included shade-tolerant slow growing species. Each mining company recorded the five most dominant tree species they planted (Table 3).

Plant Growth

Due to differences among the planted species, the plant growth in all assessed revegetation sites also differed among the companies (Fig. 2). The mean values of tree height (H) and diameter (D) in the assessed reclaimed sites generally increased with age. Besides, the selected species that are planted, the other important factors determining plant growth in post-mined site conditions are the soil properties and topography (Lamb 2011), as well as the type of extracted minerals affecting soil fertility in the mined areas (Mansur 2013). However, this study did not investigate the soil properties, so the potential influence of soils on plant establishment and growth cannot be estimated.

Table 2 Scoring of revegetation success[a]

Parameter	Assessment standard	Score
Revegetation area (actual planted area vs targeted area)	1. ≥ 90%	5
	2. 80 - 89%	4
	3. 70 - 79%	3
	4. 60 - 69%	2
	5. < 60%	1
Survival rate	1. ≥ 90%	5
	2. 80 - 89%	4
	3. 70 - 79%	3
	4. 60 - 69%	2
	5. < 60%	1
Tree density	1. ≥ 625 trees/ha	5
	2. 551 - 625 trees/ha	4
	3. 474 - 550 trees/ha	3
	4. 400 - 475 trees/ha	2
	5. ≤ 400 trees/ha	1
Species composition (long rotation species)	1. > 40%	5
	2. 30 - 39%	4
	3. 20 - 29%	3
	4. 10 - 19%	2
	6. < 10%	1
Tree health	1. ≥ 90%	5
	2. 80 - 89%	4
	3. 70 - 79%	3
	4. 60 - 69%	2
	7. < 60%	1

Note: [a]The MOEF Regulation P.60/Menhut-II/2009.

The total stem basal area (BA) is positively correlated to the crown projection area (Supriyanto *et al*. 2001) and so these values with stem numbers are good indicators of revegetation success. The highest BA value was observed in the 11-year-old stand (11A) of the NMCSS (57.6 m^2/ha) and was obtained by the prominent species *E. cyclocarpum*. However, this particular BA value that seemed exceptionally high, may have been caused by border tree effects in the small 2,000 m^2 plot, having the largest stem number. The BA values across the mining sites, varied among the assessed stand ages. In the reclaimed site of the CMCSS, the BA value of the 6-year-old stand was higher than that of the 7-year-old stand, because the 6-year-old stand had fast growing *Paraserianthes falcataria* trees and the 7-year-old stand did not. This was also observed in the GMCWJ, with the species *E. cyclocarpum* which had a higher BA value in the 3-year-old stand than in the 5-year-old stand. Possibly, based on field observations and interview, the growth stagnancy in the 5-year-old stand was due to high soil acidity (Dody Rahadi, Pers. Comm., 5 May 2016). In the CMCEK, the 2- and 4-year-old stands sampled in different locations had different BA values even though the species planted were the same *Cassia siamea*. Based on observation, this was related to a lack of plant maintenance, such as weeding, resulting in relatively poor growth at stands 2B and 4B. Different BA values were also observed in the 6- and 11-year-old stands of the NMCSS which was possibly due to differences in the number of stems and stem diameters of the species.

Table 3 Five most dominant trees planted in the reclaimed sites of the mining companies

Company	Tree species
Coal Mining Company South Sumatra (CMCSS)	*Enterolobium cyclocarpum*[a], *Swietenia macrophylla, Intsia palembanica, Melaleuca cajuputi*[a], *Tectona grandis*
Gold Mining Company West Jaya (GMCWJ)	*Enterolobium cyclocarpum*[a], *Gliricidia sepium*[a], *Melaleuca leucadendron*[a], *Syzygium polyanthum, Aporosa aurita*
Coal Mining Company East Kalimantan (CMCEK)	*Cassia siamea*[a], *Shorea leprosula, Samanea saman*[a], *Shorea balengeran, Melaleuca cajuputi*
Nickel Mining Company South Sulawesi (NMCSS)	*Cassia siamea*[a], *Vitex cofassus, Enterolobium cyclocarpum*[a], *Casuarina junghuhniana, Elmerrillia tsiampacca*

Note: [a] First planting species.

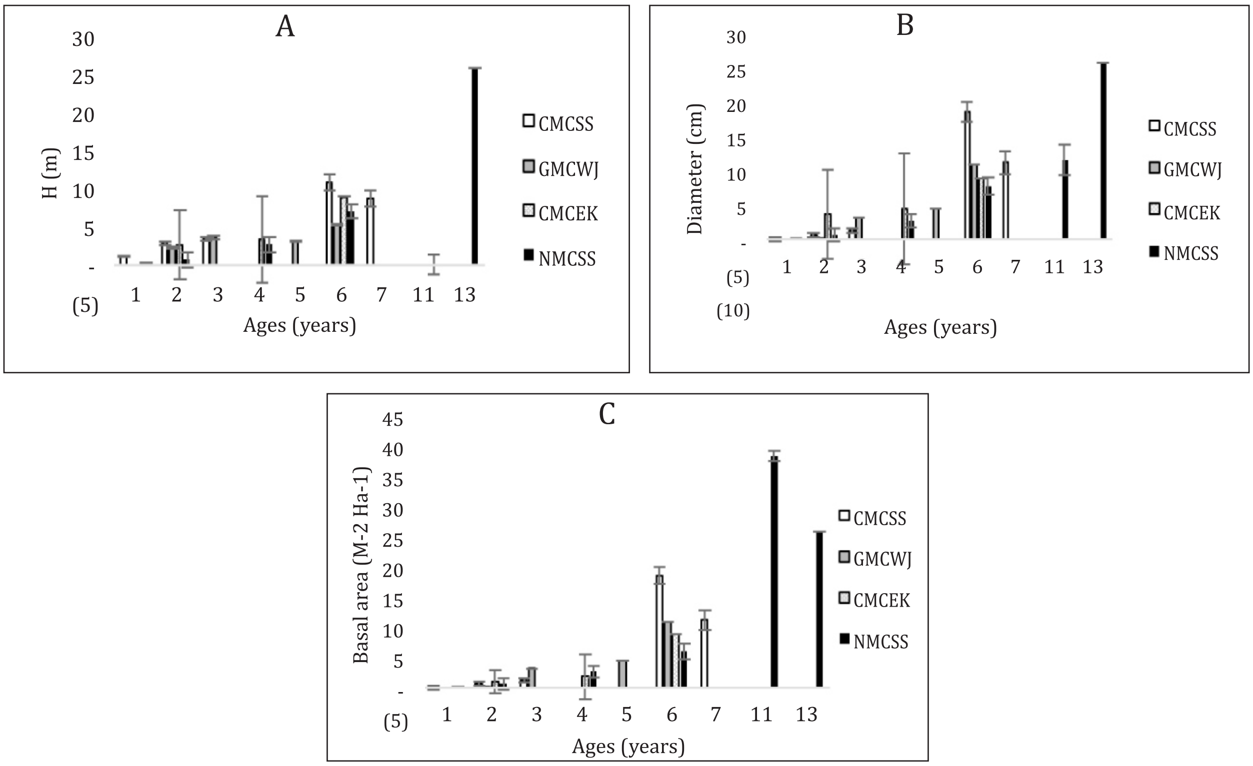

Figure 2 A = Mean tree height (H); B = mean stem diameter DBH (D); and C = stem basal area (BA) for different stand ages in the reclaimed sites

Revegetation Performance

Based on GOI regulation, the revegetation evaluation showed that values of the assessed sites ranged from 74% to ≥ 100%. This variation in the realization of revegetation protocols is usually due to some mining sites that have to be reclaimed by the planned year, but are still being used for mineral extraction and material dumping. Therefore, the actual revegetated area at these sites was lower than planned. On some sites, however, the mining activities closed earlier and so the area could be reclaimed sooner. Hence, their actual revegetation performance was higher than planned. A mining company is obliged to report to the government any deviation between the planned and the actual revegetation and will be subjected for further evaluation.

The survival rates ranged from 46% to ≥ 100% across the assessed reclaimed sites for different stand ages. The two lowest rates were found in the 3-year-old stand of the GMCWJ (46%) and in the 6- and 7-year-old stands of the CMCSS (58%). The reason for the high mortality observed in the GMCWJ was related to insufficient plant maintenance; particularly poor weeding, as the area was overrun by *Imperata* grass. In the CMCSS, the problem encountered was spontaneous coal combustion. Spontaneous fires in coal mining sites are a worldwide concern (Singh 2013). As a result of the low survival rates, the company has to replant both stands. The NMCSS, however, made considerable efforts on revegetation maintenance as they carried out careful monitoring of the plants within the first two years of establishment. Any dead plants were immediately replanted. Furthermore, weeding was continued up to year four for both first- and second-phase plantings. The two coal mining companies only weeded up to year three, whereas the GMCWJ conducted weeding as needed.

The tree density in the assessed reclaimed sites ranged from 433 trees/ha to 1,635 trees/ha (Table 4). The NMCSS had the highest plant density at stand 11A (1,635 trees/ha). The lowest stand densities were observed in the 7- and 6-year-old stands of CMCSS which was brought about by spontaneous coal combustion (Sukono, Pers. Comm., 20 April 2016). The other low-density case was found in stand 4C in the reclaimed site which was on a slope in the CMCEK, with only 450 trees/ha. As suggested, careful planning and maintenance are required for revegetating areas located along slopes. Recommended measures for areas along the slopes include: 1. planting of legume cover crops and ensuring the soil cover to prevent erosion; and 2. high stocking of pioneer and fast-growing trees in the early planting. As experienced by the CMCSS, it is essential to optimize the initial stocking density to achieve the desired final tree density.

Regarding tree health, no serious problems in terms of plant diseases and pest infestation were identified across all assessed stand ages. The common problems were mostly yellowing leaves and leafless trees. However, a crucial health problem caused by the acidic soil was found in the 5-year-old stand at the GMCWJ. The planted species of *E. cyclocarpum* and *S. saman* were mostly stunted, yellowish and without foliage during the rainy season.

Table 4 Comparison of tree density among the four mining companies

Stand age (Years)	Density (trees/ha)			
	Coal Mining Company, South Sumatra (CMCSS)	Gold Mining Company, West Java (GMCWJ)	Coal Mining Company, East Kalimantan (CMCEK)	Nickel Mining Company, South Sulawesi (NMCSS)
1	523	1,072		503
2	543	1,074	(A) 610 (B) 585 (C) 700	468
3	1,120	515		
4			(A) 893 (B) 450 (C) 803	1,328
5		960		
6	445	1,080	828	(A) 1,575 (B) 1,100
7	433			
11				(A) 1,635 (B) 985
13				1,060
*Planned tree density (N/ha)**	***750***	***1,111***	***937***	***1,400***

Note: *For the year of reclamation according to GOI approval.

In this case, it is highly recommended to replant the reclaimed site with *M. cajuputi* that can tolerate acidic soil (Doran & Turnbull 1997). Moreover, water logging was encountered in some reclaimed sites of CMCSS. In order to prevent impediments to the revegetation species, carefully planned and implemented land preparation is required. The company also took action by planting species tolerant to waterlogging, such as *Nauclea orientalis* and *M. cajuputi,* as these two species were observed to be associated with swampy areas (Orwa *et al.* 2009). Furthermore, *M. cajuputi* is fire resistant (Chokkalingam *et al.* 2007) and able to tolerate infertile soil, and the roots have aerial and adventitious growth habits in waterlogged and flooded areas (Doran & Turnbull 1997). The NMCSS also experienced some plant diseases in 2008 caused by fungal infestation of *P. falcataria*. Currently, the reclaimed sites are mostly planted with *E. cyclocarpum*. Based on field observation in this company, *E. cyclocarpum* was disease free.

In terms of rotation length, the minimum species composition required was 40% of the total living trees are long rotation trees. The percentage found in each company ranged from 0 to 93%. The 13-year-old stand in the NMCSS reached 93%, comprising 12 native long-rotation species. The notable revegetation practice of this company was the use of polyculture methods. The company had planted slow growing and long rotation length species since the first phase of revegetation. In each assessed stand of this company, the species diversity consisted of 12 to 29 species of both short and long rotation categories. Being located in a non-state forestland, the GMCWJ does not have any obligation to plant diverse species as required by the MOEF regulation. However, the company strived to plant native species. The planting stock consisted of six to 36 species of both short and long rotation. In the reclaimed sites of CMCSS, the number of species planted in each stand consisted of two to eight species of short and long rotation. The company has developed a pilot project to produce cajuput oil extracted from *M. cajuputi* ssp. *cajuputi* to enhance the sustainable land use once the concession has ceased. However, in order to improve species diversity, other species recommended for trial planting should include *Fagraea fragrans* (Mindawati *et al.* 2014) and *Alstonia scholaris* (Martawijaya *et al.* 2004). These two species can tolerate waterlogging and poor soil conditions. In the CMCEK, the species composition value was the lowest. The reason for the absence of long rotation species, particularly in the 2- and 4-year-old stands, was that the enrichment planting had not yet started. However, for stand 4A, the company can soon carry out enrichment planting since the crown shelter of the first planting is already established. To diversify the planted species, the company can also use native and long rotation species. such as *Peronema canescens* and *Vitex pubescens*, which were also planted in some reclaimed sites of this company. Maintaining species diversity in rehabilitating post-mined areas is necessary to anticipate some losses in the lifetime of the revegetation stands (Lamb 2011). Furthermore, the inclusion of endangered species in the reclaimed sites is vital for biodiversity conservation. Fortunately, the four mining companies have planted endemic species, as well as some endangered species of their respective regions.

Subsequently, each company has demonstrated its commitment to comply with the applicable regulation based on their total scores for revegetation evaluation as prescribed by the MOEF Regulation P.60/Menhut-II/2009 (Table 5). The 1- and 6-year-old stands of GMCWJ and stand 11A of the NMCSS reached a maximum score of 25. The current scoring results cannot be classified as good, medium, or poor in terms of the level of compliance since the scores have to be integrated with other parameters regarding land preparation and erosion control as required by the regulation. For the reclaimed sites that were assessed and older than three years, and with lower scores (< 20), the companies are expected to improve the growth performance through maintenance intervention.

Table 5 Comparison of mean revegetation scores among the four mining companies

Stand ages (Years)	Total scores of revegetation evaluation			
	Coal Mining Company, South Sumatra (CMCSS)	Gold Mining Company, West Java (GMCWJ)	Coal Mining Company, East Kalimantan (CMCEK)	Nickel Mining Company, South Sulawesi (NMCSS)
1	19	25		23
2	19	23	19	19
			20	
			20	
3	24	18		
4			20	24
			15	
			22	
5		18		
6	18	25	23	23
				20
7	16			
11				25
				23
13				23
Average	19	22	20	23

In the light of this study, it is suggested that an additional success criterion would be appropriately included in the revegetation assessment. The GOI can add to its evaluation a standard revegetation growth table with ranges of tree density and basal area related to the age of the reforestation. These criteria will enable both company and GOI to evaluate the tree growth, whether increasing or stagnating at a certain age. Hence, immediate measures could be taken to prevent unfavorable revegetation results. Furthermore, the assessment result will demonstrate both the quantity and quality parameters of the reclaimed sites. Lastly, based on current revegetation implementation, the common silvicultural practices, such as pruning and thinning, are hardly implemented. However, this approach should also be in accordance with applicable regulations, land use status, and the objective of post-mined area designation.

CONCLUSION

Based on field observations conducted in the four mining companies, and on the MOEF Regulation P.60/Menhut-II/2009, each mining company has aimed to comply with the regulation on revegetation with scores ranging from 15 to 25 out of 25 possible points. However, these favorable results may not be representing all the mining companies, in as much as only four companies were included, particularly those positively supporting this research. With regard to the plant growth, the results varied among the companies as the type of species planted were also varied. For the revegetation success criteria to be more comprehensive, it would be beneficial for the GOI to include the basal area growth. This criterion together with tree density could be integrated into a standard growth table related to the age of the revegetation stand. It is necessary to include these parameters so that the assessment results will demonstrate both quantity and quality of the reclaimed sites.

REFERENCES

Chokkalingam U, Suyanto, Permana RP, Kurniawan I, Mannes J, Darmawan A, Khususyah N, Susanto RH. 2007. Community fire use, resource change, and livelihood impacts: The downward spiral in the wetlands of southern Sumatra. Mitig Adapt Strat Glob Change 12:75–100. doi: 10.1007/s11027-006-9038-5.

Ditjen Planologi Kehutanan dan Tata Lingkungan (PKTL). 2017. Laporan Kinerja (LKJ) Tahun 2016. Direktorat Jenderal Planologi Kehutanan dan Tata Lingkungan, Jakarta (ID): Kementerian Lingkungan Hidup dan Kehutanan.

Doran JC, Turnbull JW. 1997. Australian Trees and Shrubs: species for land rehabilitation and farm planting in the tropics. ACIAR Monograph No. 24.

Canberra (AU): Australian Centre for International Agricultural Research. p.314-5.

Food and Agriculture Organization [FAO]. 2001. Global Forest Resources Assessment 2000 Main Report: Rome (IT).

Greb SF, Eble CF, Peters DC, Papp AR. 2006. Coal and the Environment. American Geological Institute Environmental Awareness Series, 10. Virginia (USA).

International Council on Mining and Metals [ICMM]. 2010. Mining and Biodiversity A Collection of Case Studies – 2010 Edition. London (UK).

Lamb D. 2011. Regreening the Bare Hills Tropical Forest Restoration in the Asia-Pacific Region. World Forests Volume VIII. New York (US): Springer.

Mansur I. 2013. Teknik Silvikultur Untuk Reklamasi Lahan Bekas Tambang. Bogor (ID): SEAMEO BIOTROP.

Martawijaya A, Kartasujana I, Kadir K, Prawira SA. 2004. Atlas Kayu Indonesia Jilid 2. Bogor (ID): Departemen Kehutanan, Badan Penelitian dan Pengembangan Kehutanan. Pusat Penelitian dan Pengembangan Teknologi Hasil Hutan. p.123.

McMahon G, Subdibjo ER, Aden J, Bouzaher A, Dore G, Kunanayagam R. 2000. EASES Discussion Paper Series Mining and the Environment in Indonesia: Long-term Trends and Repercussions of the Asian Economic Crisis. Environment and Social Development Unit (EASES), East Asia and Pacific Region of the World Bank.

Mindawati N, Nurohmah HS, Akhmad C. 2014. Tembesu Kayu Raja Andalan Sumatra. Bogor (ID): FORDA Press.

Orwa CA, Mutua Kindt R, Jamnadass R, Anthony S. 2009. Agroforestree Database: A tree reference and selection guide version 4.0; [cited 2017 Aug 14]. Available from: http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp.

Republik Indonesia. 2009. Peraturan Menteri Kehutanan No: P.60/Menhut-II/2009 Tentang Pedoman Penilaian Reklamasi Hutan. Berita Negara Republik Indonesia Tahun 2009 Nomor 371. Jakarta (ID).

PwC. 2015. Mining in Indonesia: Investment and Taxation Guide May 2015 – 7th Edition. Jakarta (ID): Princewaterhouse Cooper (PwC).

Singh RVK. 2013. Spontaneous Heating and Fire in Coal Mines. Procedia Engineering 62:78-90. doi:10.1016/j.proeng.2013.08.046

Supriyanto, Stolte K, Soekotjo, Gintings AN. 2001. Forest Health Monitoring Plot Establishment *In* Stuckle IC, Siregar CA, Supriyanto, Kartana J (Eds). ITTO PROJECT NO. PD 16/95 REV. 2 (F). Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest. Volume I. International Tropical Timber Organization (ITTO) and Southeast Asian Regional Center for Tropical Biology (SEAMEO BIOTROP).