Evaluation of plant species composition after thirteen years post coal mining rehabilitation in East Kutai District of East Kalimantan, Indonesia

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Abstract. Coal mining leaving large overburden which needs to be rehabilitated by conducting reclamation and re-vegetation. This study objective was to evaluate plant species composition after thirteen years of re-vegetation activities in a coal mining rehabilitation site in KutaiTimur District, East Kalimantan, with coordinate 00º33'23"-00º38'17" NL and 117º23'55"-117º23'20" EL. This study compared rehabilitation site with the natural forest conditions sites. There were found 28 plant species in the rehabilitation site, consisting of 19 wood species (*Cassia siamea* and *Ficus uncinata*) and 9 non-wood species (*Nephrolepis biserata* and *Miscanthus javanica*).In comparison, 36 species were found in the natural forest condition, consisting of 25 woody species (*Nephelium eriopetalum* and *Macaranga hypoleuca*)and 11 non-wood species (*Fordia splendidisima* and *Saurauia umbellata*). Woody species diversity indices in the rehabilitation site after 13 years post mining (i.e., 2,21) was lower than in the natural forest sites (3,01); while the diversity indices for non-wood species were relatively similar (1,48 and 1,96 in the rehabilitation and natural forest sites respectively). Species richness of non-wood species was low, but it has a high coverage per species in this site.To restore rehabilitation site woody species to its assumed natural conditions, 22woody species should be planted.

1. Introduction

The composition and plant diversity depends on a number of factors, such as elevation, slope, temperature, humidity, nutrition, sunlight, topography, bedrock geology, soil characteristics, canopy structure and land use history [1, 2]. Kalimantan is the center of species diversity, it is about 138 Shorea species were pound in and 91 of them is an Kalimantan endemic [3].

The Borneo plant diversity were disturbed by coal mining activity. Coal mining activity disturbs the function of soil profile [4] and geological structure permanently [5]. Large area of mine overburden waste land is generated annually due to open cast mining and dumped on nearby area. The overburden area has a low organic contents and physics chemistry characteristics which become unfavorable for plants growth. Considering the impact of mining to the environment, the company or people conducting mining activities has to be able to guarantee the re-productivity of land affected by mining activities [6]. The overburden area need to be restored to its pre-mining condition, therefore post-mining area needs to be rehabilitated [7].

Rehabilitation methods, such as topsoil removal have been implemented to restore abiotic conditions suitable for high diversity and threatened species call as reclamation, and it may successful by using

biological tools: tree seedlings, native shrubs, and grass species which call as revegetation [8]. The surrounding of post mining area are less fertile to be planted, in this type of location, plants grown have the tendency not to grow and develop well [9, 10]. It is important to note that mining area generally is an area that has a high biodiversity, conservation and economic [9]. Indicators of rehabilitation success is what on the ground, one of them is vegetation [11]. Post-mining area rehabilitation is considered success if the vegetation has 90% grown, close to the pre-mining condition [12]. Therefore it is important to know the reclamation success. Species richness is one of the criteria for evaluating the success of restoration which is very important in ecology [13]. In ecology, diversity in general aim to species diversity so the measurement of diversity is conducted by determining the number of species and species relative abundance in a community. The species diversity in area does not only rely on the species number found in the area but also on specify of species in it, whether the species are endemic for certain area of habitat. The plant criteria such as species composition and rate of growth is monitored, this modest vegetation measurement apart from being simple to be conducted is also sensitive [14, 15]. After rehabilitation are conducted, it is necessary to have evaluation on the success of the activity, thus making it important to conduct a study to find out the biodiversity of mining areas which have been revegetated. The objectives of the study were to evaluate plant species composition after thirteen years of revegetation activities in the coal mining rehabilitation site in East Kalimantan.

2. Method

2.1. Study area
The study was conducted at a post coal mining area in the lowlands (approximately 0-100 m above sea level) of East Kutai District, East Kalimantan Province (figure 1.A).
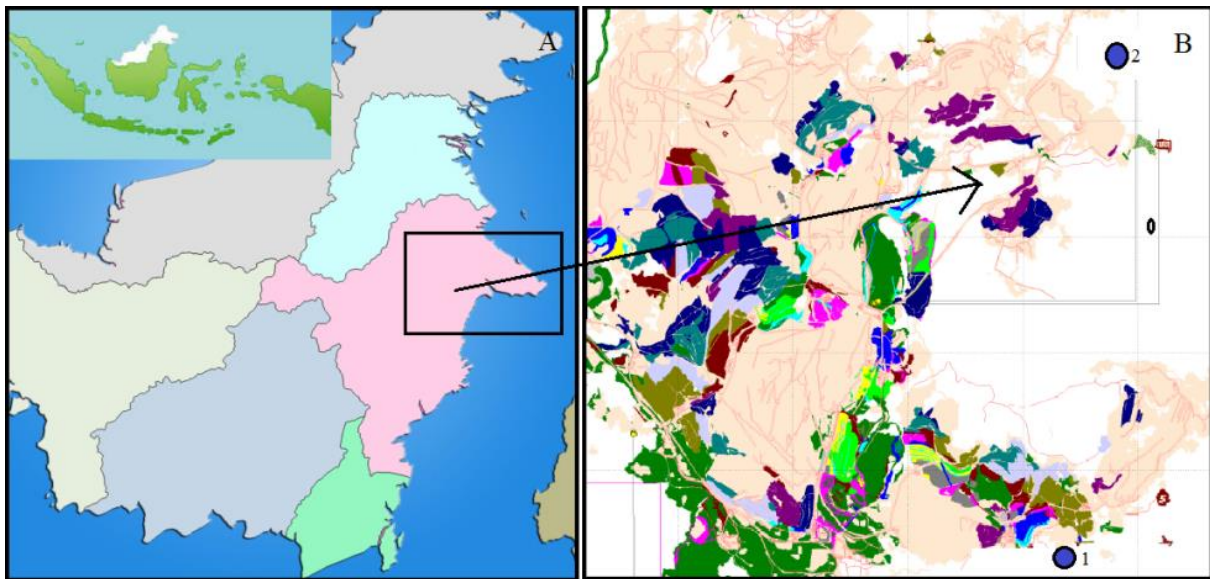

Figure 1. Location of the study area in East Kalimantan A. Blue circle 1 is the natural site and B. Blue circle 1 is the natural site and B; Blue circle 2 is rehabilitation site location.

Location of the study area in East Kalimantan at 00º33'23"-00º38'17" NL and 117º23'55"-117º23'20" EL. Borneo island. The research site was in Sangatta, East Kalimantan which has a tropical climate, with rainfall intensity characteristics varying from low to dense in a short time and can happen in a long time. average Rainfall ranges from 1543 mm per year with air temperatures minimum temperature is 26.68ºC and maximum is 30.50ºC, with a ±3ºC daily temperature fluctuation. The average

relative humidity per month between 80% - 90% with a range of 70% on afternoon and 90% in the morning. The average evaporation per month in the mine area is 4 mm/day [16].
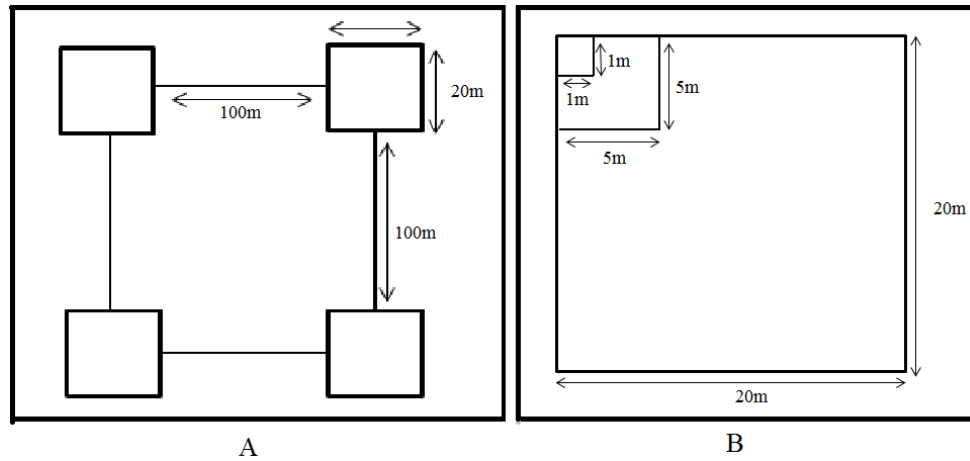

Figure 2. Plots of research in coal mining sites A .Plots in natural and rehabilitation sites, each plot measuring 20x20m^2 with 100 distance between plots; B. Plot measuring 20x20 m^2 for woody species, 5x5 m^2 for non-tree woody plants and 1x1 m^2 for herbaceous plants.

The coal mining area was previously a production forest, i.e., a forest concession area, which loaned from the Ministry of Forestry. This study was conducted in two sites: 1) a natural area and 2) a rehabilitation site which already reclamated and revegetated. Plant species composition in both the natural and rehabilitation sites was studied for a period of months (in October 2017). In both of natural and rehabilitation area, the vegetation sampling was conducted in 20 plots measuring 20x20 m^2 transects [14] with 100m^2 distance between (fig.2). The woody species were sampled in 20x20 m^2 plots, the non-woody plants is sampled in 5x5 m^2 subplots and herbaceous plants were sample in 1x1 m^2 subplots. The non-tree woody plants and herbaceous plants were grouped together. The tree and herbaceous species were collected, and if there were unknown species, it identified using references in Herbarium of East Kutai School of Agriculture, East Kalimantan, Indonesia.

The data were analyzed for frequency, density and abundance [17], their relative values were calculated as follows:

$$\text{Relative density} = \frac{\text{Number of individuals of species}}{\text{Total number of inviduals}} \times 100 \qquad (1)$$

$$\text{Relative dominance} = \frac{\text{Dominance of a species}}{\text{Dominance of all species}} \times 100 \qquad (2)$$

$$\text{Relative frequency} = \frac{\text{Frequency of species}}{\text{Frequency of all inviduals}} \times 100 \qquad (3)$$

$$\text{IVI} = \text{relative density} + \text{relative dominance} + \text{relative frequency} \qquad (4)$$

The species diversity indeces (H') were following Shannon-Wiener [7] i.e., as follows:

$$H' = -\sum_{i=1}^{S}(pi \ln pi) \qquad (5)$$

Where, H' = observed species diversity, S = the number of species; pi = the proportion of individuals or the abundance of the ith species expressed as a proportion of total cover; ln = log basen.

2.2. Data analysis
The study was conducted at a post coal mining area in the lowlands (approximately 0-100 m asl) of East Kutai District. East Kalimantan Province (figure 1).

3. Results and Discussion

3.1. Plant diversity in natural site
In the natural area we found 36 plant species, consisting of 25 woody species and non-wood plant species (tabel 1). The importance value indices of plant species in this area varied from 0.64% to 46.08%. Three species of woody plant species had importance value indices higher than 20%, specifically tree species were dominated by *Nephelium eriopetalum* (61.01%), *Macaranga hypoleuca* (22.60%) and *Croton argyratus* (21.41%) (figure 3.a). While 9 species of non-wood plants had indices higher than 15% (Figure 3), dominated by *Fordia splendidisima* (62.47%), *Saurauia umbellata* (38.21%), *Calicarpa longifolia* (37.49%), *Clidemia hirta* (27.73%) and *Homalanthus populneus* (26.95%) (figure 3.a).

3.2. Plant diversity in rehabilitation site
After 13 years of rehabilitation, we found 28 plant species which consist of 19 woody species and 8 non-wood species (tabel 1). The importance value indices of non wood plant species in this area varied from 5.29 % to 77.10%. The top 9 species with highest importance value indices were higher than 11.16% for woody species and more than 10.61% for non woody species) are presented in figure 3. Woody species were dominated by *Cassia siamea* as shown by the highest importance value index of 58.30%, followed by *Ficus uncinata* (45.49%), *Molucana falcataria* (31.52%), *Glocidion rubrum* (23.65%) and *Delonix regia* (21.26%). Non-wood species were dominated by *Nephrolepis biserata* with importance value index of 77.97%, followed by Miscanthus javanica (54.81%), Leea indica (47.97%), *Scleria purpurescens* (32.49%), *Timonius koordersii* (24.94%) and *Mesophleebion motleyanum* (21.76%).

Tabel 1. Diversity of woody species and non-wood species at natural and reclamation site (√ for present)

Woody Plant species			Non-wood plant species		
Plant species	**Natural**	**Rehabilitation**	**Plant species**	**Natural**	**Rehabilitation**
Actinodaphne bancana	√	×	*Calicarpa longifolia*	√	×
Alseodaphne nigrescens	√	×	*Clidemia hirta*	√	×
Arcidendron clipiera	√	×	*Curculigo latifolia*	√	×
Artocarpus campeden	×	√	*Ficus uncinata*	√	×
Barringtonia macrostachya	√	×	*Fordia splendidisima*	√	×
Beilschmiedia madang	√	×	*Homalanthus populneus*	√	×
Borasodendron boornensis	√	×	*Koilodepas brepipes*	√	×
Bridelia glauca	√	×	*Leea indica*	×	√
Cananga odorata	√	×	*Melastoma malabatrichum*	×	√
Canarium denticulatum	√	×	*M. motleyanum*	×	√
Cassia siamea	×	√	*Miscanthus javanica*	×	√
Cratoxylon sumatranum	√	√	*Nephrolepis biserata*	×	√
Croton argyratus	√	×	*Rubus molucanus*	×	√
Delonix regia	×	√	*Saurauia umbellata*	√	×

Dillenia excelsa	×	√	*Scleria purpurescens*	×	√
Dryobalanops aromatica	×	√	*Sentotecha lapaecea*	×	√
Eusideroxylon zwageri	√	×	*S. jagorianum*	√	×
Ficus uncinata	×	√	*Syzigium lineatum*	√	×
Glocidion macrophyllum	√	×	*Timonius koordersii*	×	√
Glocidion macrophyllum	×	√	*Trema canabina*	√	×
Glocidion rubrum	×	√			
Guensia petandra	√	×			
Litsea lancifolia	√	×			
Macaranga conifera	√	×			
Macaranga gigantea	√	×			
Macaranga hypoleuca	√	√			
Macaranga motleyana	√	×			
Mallotus paniculatus	×	√			
Melicope glabra	√	×			
Memecylon boornensis	√	×			
Molucana falcataria	×	√			
Nephelium eriopetalum	√	×			
Polyosma longipes	×	√			
Ptenandra echinata	√	×			
Ptenandra rostrata	×	√			
Samanea saman	×	√			
Switenia mahagoni	×	√			
Syzygium lineatum	×	√			
Vernonia arborea	√	×			
Vitex pinnata	√	√			

Table 2. Plant species diversity in natural and rehabilitation site

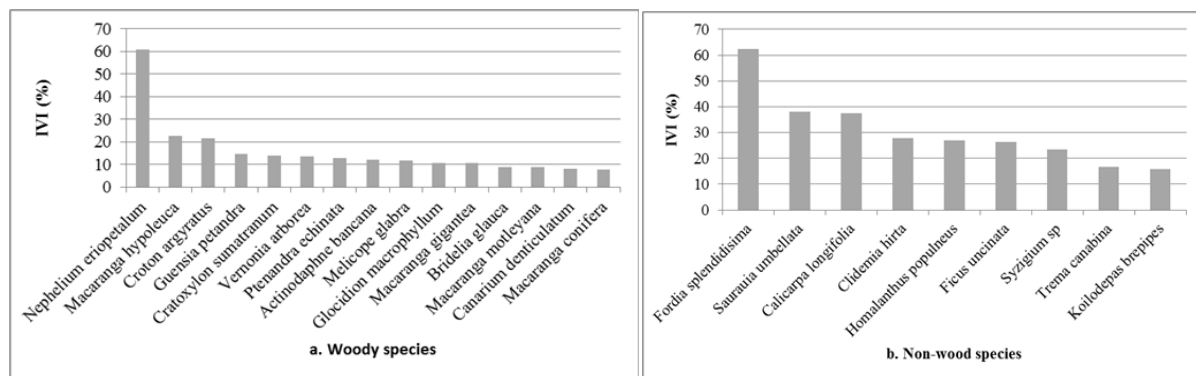|	Natural Site		Rehabilitation sites	
	Number	**H'**	**Number**	**H'**
Woody species	25	3.01	19	2.21
Non-woody species	11	1.96	9	1.48
Total Species	36		28	

Figure 3. The importance value indices (IVI) of (a). 15 species of woody species and (b). 9 species of non-wood species in natural site
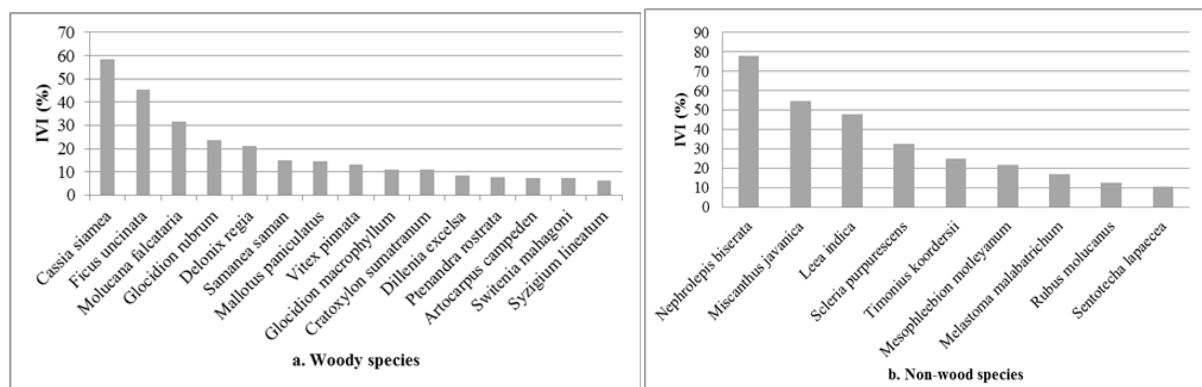

Figure 4. The importance value indices (IVI) of (a). 15 species of woody species and (b). 9 species of non-wood species in rehabilitation site

3.3. Comparison between natural and rehabilitation site

After 13 years of rehabilitation, plant diversity in the rehabilitation site was still lower than in the natural site which was used as reference. Comparison of species diversity indices (H') between the two sites indicate a significant different in woody species, however, diversity indices for non-wood plants species were similar between the two sites. The diversity index for woody species in natural area was 3.01 and in reclamation site was 2.21. Table 2 presents species richness and diversity indices in the two sites. It is interesting that between woody species of natural site and rehabilitation site is only three species the same, these are *Cratoxylon sumatranum*, *Macaranga hypoleuca* and *Vitex pinnata* (tabel 1). Between non-woody species of natural site and rehabilitation site is no same species.

3.4. Discussion

As shown by its highest importance value index, natural site were dominated rambutan hutan (*Nephelium eriopetalum*), which is a local species. It has a high value indeces perhaps because of its easy to grow. *Macaranga hypoleuca* was the second dominant species in the natural site, it is known as fast growing species. *Macaranga hypoleuca* is a sub-canopy tree growing up to 30 metres tall, it can be 30 – 40 cm in diameter. Many of *Macaranga* sp is tolerance to open areas. In the rehabilitation site, the dominant species was johar (*Cassia siamea*). However, *Cassia siamea* was quite abundant because the company planted a seedlings, which became one of the factors contributing to the importance value

indices of these plant species is the high number of seedlings of local species planted in the rehabilitation site. There is only three woody species from the natural site can grows in the rehabilitation site (*Cratoxylon sumatranum* (13.72%), *Macaranga hypoleuca* (22.60) and *Vitex pinnata* (6.27)). There is three possibility first because it planted by the company, the second one is because of seeds already present in the top soil during reclamation process, and its grow when the condition is suitable and the third its because of the seed dispersal. The dominant non-wood species in natural site is *Fordia splendidisima* with the highest importance value index (62.47%) and the dominant non-wood species in the rehabilitation site was the *Nephrolepis biserata* with an importance value index of 54.81%. *Fordia splendidisima* extremely tolerant to minimum light intensity (shade plant). *Nephrolepis biserata* is tolerant to high light intensity. The non-wood species found in the rehabilitation site was not found in the natural sites (*Nephrolepis biserata* and *Miscanthus javanica*). The ability of plants to grow in the rehabilitation site can be attributed by seed dispersal. Perhaps dispersed by wind from the forest system, except *Leea Indica* which may dispersed by animal. The distance between the rehabilitation site to the nearby vegetation source and animal species and will affect the plant species dispersion e.g., the nearest forest that will affect the distribution of the species (Traveset et al. 2014).

Based on the number of plant species at rehabilitation site, to restore plant diversity in the rehabilitation site to its assumed natural conditions, it should be planted with 22 woody species. The species importance value indices can be considered a to select the woody tree species from the natural area. In the natural area, only ten local species had importance value indices higher than 10%, and 9 of them was not in the rehabilitation plant species e.g., *Nephelium eriopetalum* (61.01%), *Croton argyratus* (21.41%), *Guensia petandra* (14.59%), *Vernonia arborea* (13.35%), *Ptenandra echinata* (12.78%), *Actinodaphne bancana* (12.11%), *Melicope glabra* (11.64%), *Glocidion macrophyllum* (10.72%) and *Macaranga gigantean* (10.65%). The availability of seedlings and the ability of the plant to grow successfully can be considered in the rehabilitation program of coal mining rehabilitation condition.

4. Conclusions

After 13 years of rehabilitation, 28 plant species were found in the rehabilitation site, consisting of 19 woody species and 9 herbaceous species. In comparison, data from the natural area indicate the presence of 36 plant species, consisting of 25 local woody species and 11 non-woody species. Woody species diversity index in the rehabilitation site after 13 years post mining (i.e., 2.21) was lower than in the natural area (3.01); while the diversity indices for non-woody plants were relatively similar (1.48 and 1.96 in the rehabilitation and natural sites respectively). Although its species richness of non-wood species was low, but it has a high coverage per species in this site. To restore plant diversity in the rehabilitation site to its assumed natural conditions, it should be planted with 22 woody species.

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